Benefit-Cost Analysis of the U.S. Climate Resilience Toolkit

based on case studies from the Southeast

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Contents

Foreword

A steady increase in the number of billion-dollar disasters[1] related to climate has an enormous impact on our nation and its cities, resulting in a call to action to build resilience at the local scale. There is an increasing demand for climate services, which creates opportunities for new businesses and new careers.[2] The pain that local communities face stimulates demand for climate science-based information, resulting in job creation and the emergence of a new business sector.

The U.S. Climate Resilience Toolkit (CRT) fills a leadership role by providing key information with which to frame the climate resilience issue and a process others can use to move beyond identifying the climate problem to actually implementing solutions. The CRT helps our society move from asking *why* we should build resilience to asking *what* should actually be done. It also introduces a risk assessment process to answer the question of *how* to build resilience at multiple scales.

In mid-2018, NOAA OAR Climate Program Office (CPO) program leaders were asked to report on the question, "What are the economic benefits of your work/investments?" David Herring, Chief of the Communication, Education and Engagement Division of CPO, approached the Director of UNC Asheville's National Environmental Modeling and Analysis Center (NEMAC), Jim Fox, for his input in answering this question as it relates to the CRT. This paper builds on earlier versions delivered to Mr. Herring in a beginning attempt to quantify the CRT's direct economic impact.

Why was the CRT developed? According to the site itself, its goal is to "improve people's ability to understand and manage their climate-related risks and opportunities, and to help

[1] NOAA National Centers for Environmental Information (2019): U.S. Billion-Dollar Weather and Climate Disasters.
[2] Environmental Business International (June 2019): *EBI Report 4800: Climate Change Adaptation & Resilience Markets, A Climate Change Industry Business Segment Review,* Part of the EBI Report 4000 Series on the Climate Change Industry. San Diego, CA: Environmental Business International, Inc. Hereafter referenced as "EBI Report 4800." Figure 1-7.

them make their communities and businesses more resilient to extreme events."[3] The site was launched in 2014, concurrent with the initiation and national cohesion of climate and/or community resilience assessment work into a new field of endeavor: quantitatively building community resilience. Thus, a new type of work/career—the resilience professional—is in the process of being created, supported by the CRT. The CRT does not, however, operate in a vacuum, and other factors—including the development of groups such as the American Society of Adaptation Professionals (ASAP), the Urban Sustainability Directors Network, the Association of Climate Change Officers, the National Adaptation Forum, and others—have also supported the field's growth. Therefore, we cannot attribute all economic activities associated with the field's development to a single factor such as the CRT. Rather, the CRT can be considered a catalyst that is supporting the growth of resilience products and services.

This paper examines known impacts to the regional economic system relating to climate resilience and adaptation in which NEMAC operates, mainly the southeastern United States, and measures only impact in the sphere with which NEMAC is familiar. The results can be used to calculate a valuation of national impact through a statistical summation; however, that work is beyond NEMAC's expertise and the scope of this paper.

We recommend that experts, both within NOAA and outside the agency, be engaged to conduct an economic impact analysis (EIA), with a particular focus on benefit-cost ratio. An EIA estimates how spending associated with a particular event—in this case NOAA, CPO and the CRT, and other groups associated with NOAA—flows through a regional economy. Within NOAA, we invite NOAA's chief economist to perform a more rigorous analysis using a case study approach. We also point to ASAP as a potential key partner to manage coordination of this work outside the agency, as it represents the national/regional economy being impacted.

The NEMAC team has been working on the CRT with the CPO team since 2014. During that time, we have leveraged that partnership to obtain new revenue streams and to create a private spin-off—FernLeaf—and the public-private partnership known as NEMAC+FernLeaf. The risk assessment process embodied by the Steps to Resilience is an essential element of our current work and our future career paths. We believe that the growing group of resilience professionals can provide similar data- and viewpoints to our own. In short, the CRT has provided a firm foundation for our team, and we look forward to working with like-minded professionals to build a better tomorrow.

[3] U.S. Federal Government (2014): "Frequently Asked Questions," *U.S. Climate Resilience Toolkit.* Accessed 29 March 2019.

Summary of Findings

To determine the estimated benefit-cost ratio (BCR) for the CRT in the Southeast, we first calculate the "cost" as the amount of money that CPO has invested in NEMAC to create and support the CRT since its inception.

TOTAL COST: $1,125,000 (FY2015–FY2020)

To calculate the "benefit," we sum the amount of estimated benefits associated with investments made in projects related to NEMAC work. This benefit amount has greater uncertainty than the cost amount quoted above, but we estimate it to be at least $6 million, and possibly twice that number.

1.	Loss Avoidance—Losses and costs avoided	$4,730,000
2.	Capacity Building—Creation of jobs and career paths	$792,000
3.	Capacity Building—Standardization of the resilience process	$500,000
4.	Capacity Building—Reduction of future losses by resilience champions	$100,000
5.	Additional economic benefit (not valued due to current large uncertainty	$0
	TOTAL BENEFIT	$6,122,000

ESTIMATED BENEFIT-COST RATIO: 5.44

The calculations of cost, benefit, and the benefit/cost ratio are more fully discussed in the following sections, which are presented in two parts. We first provide background and framing of climate resilience and adaptation at the national scale with a discussion of the primary value metrics and assumptions made for costs and benefits. This is followed by a case study focused on the work of our group—UNC Asheville's NEMAC—in the southeastern United States, which examines known impacts to the regional economic system relating to climate resilience and adaptation in which we operate and measures only impact in the sphere with which we are familiar. The case study section provides detailed discussion of the value metrics for costs and benefits, attributes estimated values, and calculates the estimated BCR.

Introduction

After review of the natural hazard mitigation and climate adaptation literature, we recommend the use of the benefit-cost ratio (BCR) for comparability of results across studies. The BCR expresses the value of benefits achieved for each dollar spent, calculated by dividing the value of benefits achieved by the costs expended. A 4:1 BCR, for example, means that four times the benefits are realized compared to the costs invested.

BCR is a metric used in a benefit-cost- analysis (BCA), and is the most commonly used approach in the adaptation and resilience sector. Personal communication with economists at NOAA, the Federal Emergency Management Agency (FEMA), and several non-governmental and nonprofit organizations confirms that BCR and the associated benefit-cost analysis (BCA) are the most appropriate metric and methodology to use. Perhaps the best justification comes from the White House Office of Management and Budget in Circular A-94: "Benefit-cost analysis is recommended as the technique to use in a formal economic analysis of government programs or projects."[4]

Further confirmation is found in the recent FEMA Building Resilient Infrastructure and Communities (BRIC) funding announcement, which states that all projects must have at least a 1.0 BCR to be considered for funding. FEMA provides the following guidance about BCR on its website:

> Benefit-Cost Analysis (BCA) is the method by which the future benefits of a hazard mitigation project are determined and compared to its costs. The end result is a Benefit-Cost Ratio (BCR), which is calculated by a project's total benefits divided by its total costs. The BCR is a numerical expression of the "cost-effectiveness" of a project. A project is considered to be cost effective when the BCR is 1.0 or greater, indicating the benefits of a prospective hazard mitigation project are sufficient to justify the costs.[5]

We therefore recommend following this national standard.

Note that while the calculations of BCA and BCR have long been used in economics, their application to climate resilience has not. Almost all mentions in the literature of their application in the climate resilience space post-date the launch of the CRT.

The Urban Land Institute aptly describes the problem in its 2015 study on resilience returns:

> ULI selected the projects in this report because they demonstrate that resilience strategies can create value. In this relatively new field of resilience, developers and

[4] U.S. Office of Management and Budget (2012): "OMB Circular A-94: Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs."
[5] Federal Emergency Management Agency (2020): "Benefit-Cost Analysis."

> property owners may not have solid metrics and clear financial analysis on the cost-effectiveness of their efforts because their design and construction strategies may not have had extensive testing by the elements.[6]

In other words, most of the resilience investments being made today contain an inherent degree of uncertainty because we do not yet know how truly effective they will be in the face of a changing climate.

A study by the National Institute of Building Sciences Multihazard Mitigation Council[7] highlights the benefit of economic support for building resilience, calculating that dollars invested in resilience offer at least a 4:1 benefit-cost ratio compared to investing after a disaster strikes. This study sums all costs allocated to building resilience and then calculates community benefit, examining a post-disaster scenario.

These studies and others listed in Appendix A recommend that benefits be attached to two major categories: loss avoidance and capacity building. We adopt those recommendations and present our results herein accordingly.

BCR is, of course, only a beginning point for a full economic analysis. Other value drivers—including those that are non-monetary—are important to consider, particularly the concepts of equity and socioeconomics. That work, however, is beyond NEMAC's expertise and the scope of this paper.

[6] Urban Land Institute (2015): Returns on Resilience: The Business Case. ULI Center for Sustainability. Washington, DC: The Urban Land Institute.

[7] Multihazard Mitigation Council (2018): *Natural Hazard Mitigation Saves: 2018 Interim Report*. Principal Investigator Porter, K., co-Principal Investigators C. Scawthorn and C. Huyck, Investigators R. Eguchi, Z. Hu, A. Reeder, and P. Schneider, Director, MMC. Washington, DC: National Institute of Building Sciences; Multi-Hazard Mitigation Council (2019): *Natural Hazard Mitigation Saves: 2019 Report.* Principal Investigator Porter, K.; co-Principal Investigators N. Dash, C. Huyck, J. Santos, and C. Scawthorn, Investigators M. Eguchi, R. Eguchi, S. Ghosh., M. Isteita, K. Mickey, T. Rashed, A. Reeder, P. Schneider, and J. Yuan, Directors, MMC. Investigator Intern A. Cohen-Porter, Washington, DC: National Institute of Building Sciences. Hereafter referenced jointly as "Natural Hazard Mitigation Saves."

Metrics and Assumptions

In any benefit-cost analysis, it has been found to be easier to measure costs than to estimate benefits. Benefits are multi-faceted and accrue over time, whereas costs are investments (mainly, in this case, for man- or woman-power) across a specific period of time.[8] The primary shortfall in this approach occurs when benefit is assigned to a single stakeholder when the investment was actually made by multiple stakeholders. For instance, case studies presented in this report highlight vulnerability and risk assessments funded by individual cities, but the cost of those assessments has not been incorporated into our analysis. Of course, the reverse is also true—groups other than NEMAC have benefited (either directly or indirectly) from the investment that NOAA continues to make in climate products and services across the entire enterprise.

With these factors in mind, this section explains the logic we applied to address the uncertainty associated with a calculation of costs. We use Hubbard's definition of, and method of measurement for, uncertainty: "The lack of complete certainty, that is, the existence of more than one possibility. The "true" outcome/state/result/value is not known. To measure uncertainty, a set of probabilities are assigned to a set of possibilities."[9]

Benefit-cost ratio (BCR) is calculated by dividing total benefits by total costs. We know exactly how much NOAA paid to NEMAC for its work on the CRT ($1,125,000 for FY15–FY20), for the co-creation, hosting, maintenance, and outreach associated with the tool. What we don't know is the percentage of this amount we should use for the "cost" side of the BCR calculation. We could use a percentage approach, with percentages ranging from 20 percent ($225,000) to 50 percent ($562,500) to the total value of 100 percent ($1,125,000). We do not know what value NOAA assigns to our role in the CRT's development; therefore, we value NOAA's cost at total value (100 percent) in our BCR calculation. The effect of using other cost percentage rates on the calculated BCR is discussed further below.

Our working assumptions are enumerated below and presented in a logical sequence, with some explanation and examples provided to help "ground" each assumption. Using this approach, this section attempts to address uncertainty around each of the key assumptions.

[8] Hubbard, Douglas W. (2014): "Chapter Four: Clarifying the Measurement Problem." In: *How to Measure Anything: Finding the Value of "Intangibles" in Business*, Third Edition. Hoboken, NJ: Wiley.
[9] Hubbard, Douglas W. (2014): *How to Measure Anything: Finding the Value of "Intangibles" in Business*, Third Edition. Hoboken, NJ: Wiley.

Cities face growing climate-related risks

In the face of climate-related risk, cities are investing in building resilience. The Federal Government also recognizes that risk and is willing to fund projects to build resilience.

The CRT and its associated Steps to Resilience were published in 2014 as a result of a growing demand for resilience tools and a risk assessment process outlining the best way to use federal science agency data and products. Also of note is that, in 2019–2020, FEMA announced a new funding program to address climate resilience issues. Titled "Building Resilience for Infrastructure and Communities" (BRIC), the pre-disaster hazard mitigation program will utilize a six percent set-aside from monies allocated to states for disasters. The program is a result of amendments made to Section 203 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act). The adoption of this program and the amendments to the Stafford Act that allowed it serve as a significant statement from both FEMA and the U.S. Congress: there is proven benefit to the use of a BCR (greater than 4:1) for investing in resilience compared to response and recovery.

City leaders understand—as do municipal bond rating agencies—that their risk is increasing due to a changing climate and that their risk will continue to increase unless they invest in resilience.

"Losses and costs avoided" reflect direct savings for communities.[10,11] Because of the factors hindering more rapid adoption of climate mitigation options, the CRT focuses on climate adaptation and resilience. The site encourages communities and businesses to invest in resilience as a means to avoid future losses and costs from increasing climate-related hazards.

In calculating the value of loss avoidance, we consider the fact that the more rapidly our society can build resilience, the greater the amount of future losses that can be avoided and thus the greater the economic impact overall.[12] If our society simultaneously builds resilience *and* finds solutions that address mitigation, we could realize a double benefit.

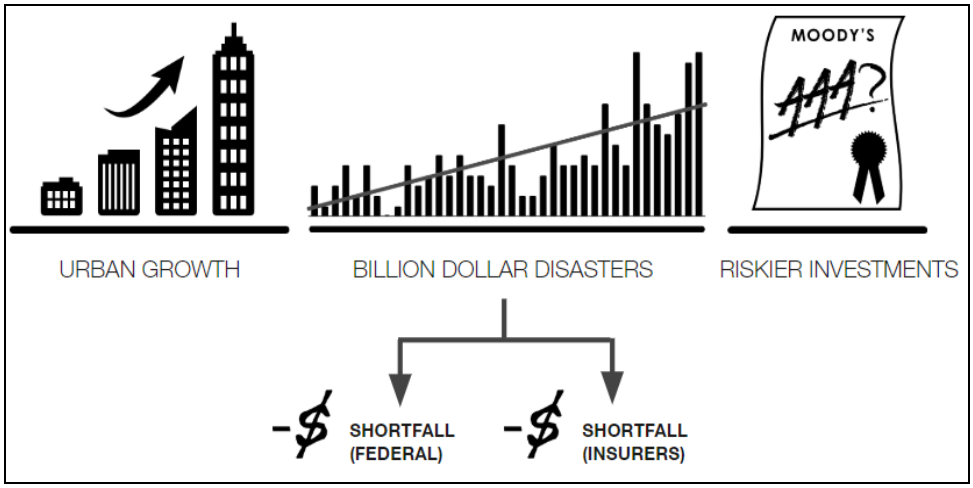
Avoiding losses and costs associated with climate-related events provides the benefit of allowing communities and businesses to invest their limited dollars in other strategic improvements. Another clear benefit is the avoided revenue loss from business interruptions due to climate-related events. Options to build resilience implemented by a community or a business can drastically lower this cost, providing a very clear benefit.

[10] *Natural Hazard Mitigation Saves* (2018), pp. 1.
[11] Global Commission on Adaptation (2019): *Adapt Now: A Global Call for Leadership on Climate Resilience*. Washington, DC: World Resources Institute. Hereafter referenced as "Adapt Now." pp. 3.
[12] Norton, Rachel, Karen MacClune, Michael Szönyi, and Jennifer Schneider (2019): *Hurricane Florence: Building Resilience for the New Normal.* Schaumburg, IL: Zurich North America.

Implementable resilience options can realistically only be identified and prioritized after the community has undertaken a quantified resilience assessment—an assessment, in many cases, that follows the CRT's Steps to Resilience or a comparable framework.

A community, of course, will experience loss and associated costs when it must fund recovery efforts after a weather-related event, and can perhaps avoid them if it proactively plans before the occurrence of such an event. In order to effectively plan, communities must be aware that two primary stressors drive the new realities in the U.S.: continued urban growth (a non-climate stressor) and accelerating billion-dollar disasters (climate stressors).

The majority of our national economy, including jobs, is driven by urban areas.[13,14] As citizens, we have expected federal, state, and local governments to help support this infrastructure. We also carry insurance to protect these economic interests and jobs. However, some are finding that there is a shortfall between funding received from the Federal Government and any insurance coverage and the full amount needed to recover from a disaster. This leaves local governments, and citizens, to cover the remaining amount—roughly 30 to 50 percent, as shown in the example below examining the impact of Hurricane Florence in North Carolina.[15]

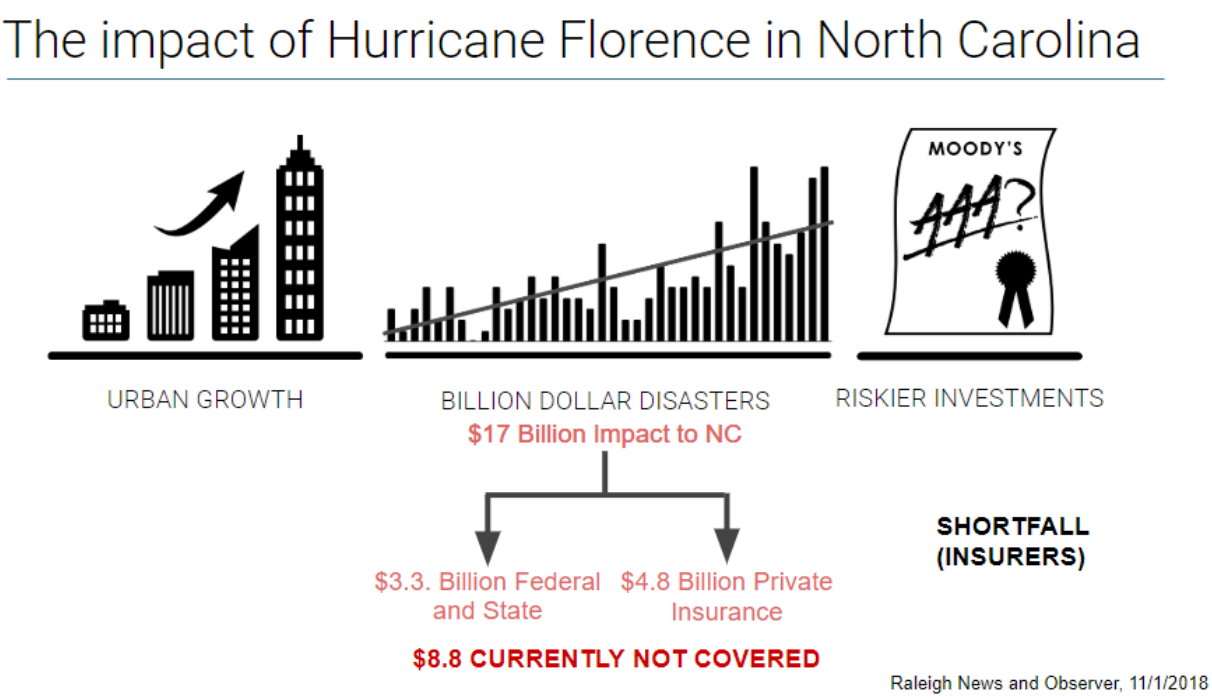


Local governments are learning that investing in resilience pays big dividends—according to recent FEMA studies, an estimated 4-to-1 return ratio.[16,17] Perhaps more importantly, bond rating agencies are also learning this lesson. Cities issue municipal bonds to fund capital improvements; their bond ratings determine the interest rate they pay. Moody's Corporation, a

[13] Dobbs, Richard, Sven Smit, Jaana Remes, James Manyika, Charles Roxburgh, and Alejandra Restrepo (2011): *Urban world: Mapping the economic power of cities.* San Francisco: McKinsey Global Institute.
[14] Hindlian, Amanda, Sandra Lawson, Sonya Banerjee, Dan Duggan, and Michael Hinds (2019): *Taking the Heat: Making cities resilient to climate change.* New York: Goldman Sachs.
[15] Stradling, Richard, and Abbie Bennett (2018): "'Historic' Hurricane Florence caused more damage than Matthew and Floyd combined, governor says," *Raleigh News & Observer.* Published October 31, 2018, updated November 2, 2018.
[16] Davlasheridze, Meri, Karen Fisher-Vanden, and H. Allen Klaiber: "The effects of adaptation measures on hurricane induced property losses: Which FEMA investments have the highest returns?" *Journal of Environmental Economics and Management* 81 (2017): 93–114.
[17] *Natural Hazard Mitigation Saves.*

bond rating agency, has put municipalities on notice that there will be a "growing negative credit factor for [bond] issuers without sufficient adaptation and mitigation strategies."[18] In fact, in July 2019 Moody's announced that it had acquired a majority stake in Four Twenty Seven, Inc., a leading provider of data, intelligence, and analysis related to physical climate risks, stating that the acquisition solidified its commitment to promoting "transparent and globally consistent standards for evaluating environmental, social, and governance (ESG) risks and opportunities."[19]

EXAMPLE



An estimated $8.8 billion in damages from Hurricane Florence suffered in North Carolina will not be covered by federal or state funding or private insurance.[20] The amounts cited are from North Carolina Governor Roy Cooper's office, and indicate the scale of this problem. The impacts are across multiple sectors and will be felt for years. North Carolina will not receive additional federal funding to cover the shortfall—so local businesses, communities, governments, and individuals will pay these "uncovered costs." What if we had made a dedicated move toward climate resilience? Could the amount of these losses have been reduced, or perhaps avoided altogether? We don't know the answers to these questions, but we are pleased that the State of North Carolina actively followed the CRT's Steps to Resilience in developing its *Climate Risk Assessment and Resilience Plan*, released in June 2020.[21]

[18] Moody's Investors Service (28 November 2017): "Announcement: Moody's: Climate change is forecast to heighten US exposure to economic loss placing short- and long-term credit pressure on US states and local governments." See also Perkins+Will (5 March 2015): "DDOE Climate Adaptation Planning."
[19] Moody's Corporation (24 July 2019): "Moody's Acquires Majority Stake in Four Twenty Seven, Inc., a Leader in Climate Data and Risk Analysis." See also Flavelle, Christopher (24 July 2019): "Moody's Buys Climate Data Firm, Signaling New Scrutiny of Climate Risks," *The New York Times*.
[20] Ibid.
[21] State of North Carolina (2020): *North Carolina Climate Risk Assessment and Resilience Plan: Impacts, Vulnerability, Risks, and Preliminary Actions. A Comprehensive Strategy for Reducing North Carolina's Vulnerability to Climate Change*. Published June 2020.

City leaders value the CRT

In 2013, as cities began to build resilience to a changing climate, The Rockefeller Foundation founded (and funded) the 100 Resilient Cities network to help them develop resilience plans and begin to invest in resilience projects.[22] Those cities that were fortunate enough to receive funding then had a mechanism to not only undertake planning, but also to hire support staff and consultants to aid in implementation of their plans. This laudable effort, however, involved only a small collection of cities that recognized that they needed help to build resilience.

Other cities outside the 100RC network also knew that they needed assistance—but they didn't have access to immediate funding or support. Some worked together, some went it alone, and some approached the Federal Government for support. Through the CRT, all cities can access guidance on best practices and tools for building resilience. It is important to note that the cities described in this report's case studies section were not a part of the 100RC network, nor did they receive funding from The Rockefeller Foundation. They had to invest their own dollars. Their decisions to invest municipal funds in the process outlined in the CRT itself speaks volumes about the perceived positive benefit of the tool.

City officials' positive perceptions of the CRT (which includes the Steps to Resilience framework, the Climate Explorer tool, and the site's collection of case studies) influenced their decision to use it to help guide their resilience planning processes. Officials of the cities cited in this report selected the CRT's Steps to Resilience framework because they saw greater value in it than they saw in other options available on the market, in part because they perceived that it had been used by others in achieving successful resilience-building outcomes. This perception is based, in part, on the collection of more than 100 success stories found in the CRT's case studies section that clearly connect real-world outcomes with the Steps to Resilience and, in part, on their perception of the CRT's authority, credibility, and relevance to their resilience planning objectives.

Anecdotally, one great story about the positive perceived value of the CRT comes from the City of Tallahassee, Florida. Not only did city officials base their planning request for proposals on the CRT's Steps to Resilience, they also chose a contractor who could implement the process. During the interview, Tallahassee's City Manager stated, "I want a Cadillac but can only pay for a Chevy—the CRT allows me to fulfill this desire."

[22] The Rockefeller Foundation (2020): "100 Resilient Cities."

Cities benefit from using the CRT and the Steps to Resilience

City officials—and the cities they serve—benefit by using the CRT. Its Steps to Resilience framework provide city officials with some measure of efficiency in the process of co-producing information that leads to a shared understanding of their exposure to climate-related hazards; a quantification of their vulnerabilities and risks associated with those hazards; a prioritized list of viable, cost-effective actions for risk mitigation and resilience building; and an action plan that they will implement, or have implemented, designed to produce measurable real-world outcomes.

Anecdotal evidence of this benefit can be found; we note particularly the opinion issued by the Editorial Board of Charleston's *Post and Courier* newspaper, referencing the city's Dutch Dialogues process and the All Hazards Vulnerability and Risk Assessment completed by NEMAC+FernLeaf in January 2020:

> That critical work *[the vulnerability assessment, based on the CRT]* will dovetail into an updated capital improvement plan for flood projects. The city has estimated it has $2 billion worth of needs in this area, and Mayor John Tecklenburg must secure the funding to make significant progress. The new plan, also expected this year, will be different because it will be a database, not a list. It will help city officials analyze projects not only by their costs and potential flood reduction but also based on future maintenance costs, social justice impacts and environmental benefits. One important lesson...is that flood projects can and should have public benefits—such as recreation and transportation—aside from simply managing water. It will help show where the city gets its best return for limited public dollars, and it can be updated as climate projections change.[23]

Charleston's Chief Resilience Officer, Mark Wilbert, described the planning process during a radio interview with South Carolina Public Radio in September 2019, "The vulnerabilities drive you to be resilient or not. And if you're not resilient, then you're not going to be around very long."[24]

Assumptions associated with valuations of benefits

Some benefits realized by cities from using the CRT can be observed and quantified, but the valuation is associated with a range of uncertainty. Also uncertain is the amount of benefit

[23] Editorial Board (2020): "Editorial: Finally, Charleston adopts a comprehensive flooding strategy. Now the hard part begins," *The Post and Courier.* Published January 18, 2020, updated April 14, 2020.
[24] Hansen, Victoria (2018): Charleston's Chief Resilience Officer Fights Flooding and Sea Level Rise, interview of Charleston Chief Resilience Officer Mark Wilbert by Victoria Hansen for the program *South Carolina Focus*. South Carolina Public Radio, published March 7, 2018.

directly assignable to the CRT. Specific actions have been taken and specific investments were, or will be, made by city officials based on their climate resilience planning following the CRT's Steps to Resilience framework. These investments fall into two major categories: (1) loss avoidance, and (2) capacity building. The benefits arising from loss avoidance are the largest, but also carry the greatest uncertainty. The headings used for each of these assumptions are also used in presenting each case study.

Assumption 1. Loss avoidance

For benefits related to loss avoidance, there are two large and separate sources of uncertainty. The first relates to the effectiveness of resilience projects that have been implemented: if a comparable hazard of similar magnitude has not occurred after the date the project in question was implemented, we can only assume that the project really did build resilience. The second relates to the role that the CRT played in the implementation of resilience projects. We know that the CRT has had a positive influence on the decision process; however, we don't know the percentage of benefit that can or should be assigned to it. In our research, NEMAC has not identified any published studies that provide guidance on how to handle this type of uncertainty. It is also important to note that some financial information included herein is confidential or proprietary, as it has not yet been publicly released by the named cities, and that information may require revision at a later date based on final reports as they become public.

The initial calculation for BCR involves how much benefit a resilience action provides to a community. If we make the assumption that the community uses some funding provided by FEMA or the U.S. Army Corps of Engineers, we know that both of these agencies require that the project provide a BCR of at least 1, and preferably 2, in order to be funded.[25] For ease of calculation, and assuming we know the project's cost, we assume a beginning benefit equivalent to the cost. This is the approach taken in the Charleston, West Palm Beach, and Tallahassee case studies presented in the next section of this report. However, unless the community has experienced similar climate-related hazard events before and after the investment, we do not know the true benefit of the resilience project—and therefore a great deal of uncertainty remains associated with the calculated benefit. Note that the Asheville case study involves comparable flood events and presents comparable impact numbers, which greatly reduces the uncertainty associated with the loss avoidance benefit calculation in that instance.

The second calculation for benefit associated with loss avoidance relates to the percentage that can or should be attributed to the use of the CRT and its associated Steps to Resilience. We assume that the CRT helped the community make better decisions than would have been made without it, saving both time and money. The savings could be related to, among other

[25] Federal Emergency Management Agency (2009): *Final BCA Reference Guide*. Washington, DC: Department of Homeland Security (June 2009); Durden, Susan E., and Jim Fredericks (2009): *Economics Primer*, IWR Report 09-R-3. Alexandria, VA: U.S. Army Institute for Water Resources, U.S. Army Corps of Engineers (June 2009).

things, avoiding labor costs from using the provided risk assessment process, cost savings from avoiding investments in projects that do not build resilience, or cost savings from investing in projects that build resilience but do not focus on the most important or time-critical measures. All of these factors are assumed, so the benefit calculation involves a great deal of uncertainty. For this reason, we have attributed only a very small percentage of benefit to the CRT: one percent, two percent, or five percent. Furthermore, we have considered the benefit of the CRT to "expire" five years after a city's vulnerability assessment—i.e., any investment a city makes five or more years after its CRT-based assessment should not be attributed to the CRT—as we assume that personnel changes and other factors would, over time, lessen or negate the benefit provided by the CRT.

Based on the above discussion, in the case study section of this report we separate the two categories of uncertainty associated with loss avoidance benefit, presenting the findings to illustrate the range of uncertainty and the one that was used for the calculation.

Assumption 2. Capacity building—creation of jobs and career paths.

Benefits can be obtained not only by loss avoidance, but also in building capacity in the workforce. The calculations for capacity building are much more straightforward than those for loss avoidance. Building workforce capacity gives communities more options for resilience building and results in a trained workforce that can continue climate adaptation activities into the future. New career paths and job categories directly linked to resilience planning are being created, usually involving the oversight and/or facilitation of resilience work in a municipal role or performance of work for and by consultants or other service providers. We see evidence of this new job type through:

- Rapid growth in the U.S. climate change adaptation and resilience industry since 2014, as reported by *Environmental Business International*.[26] Fields such as climate change adaptation and resilience services, disaster services, and climate adaptation equipment and services have seen an estimated 15 percent annual growth, with many of the services supporting federal and local governments. Additionally, the nationwide "climate adaptation and resilience services" sector generated $960 million in 2014, $1,760 million in 2018, and revenues are projected to be $2,330 million by 2020.[27]

- Growth in the adaptation profession, as evidenced by the number of members affiliated with organizations such as the American Society of Adaptation Professionals (ASAP), the Urban Sustainability Directors Network (USDN), and others. As of July 2020, ASAP had 1,427 members from 49 states and 590 organizations; USDN had over 200 member communities consisting of cities and counties in the U.S. and Canada, representing over 90 million residents.

[26] *EBI Report 4800*, Figure 1-82.
[27] *EBI Report 4800.*

- Growth in the number of professional conferences and certification workshops, such as the National Adaptation Forum and numerous regional climate resilience forums convened by NOAA RISA and other federally funded partners. For example, the first National Adaptation Forum—the largest climate adaptation conference in the United States—was held in Denver, Colorado, in 2013, with an estimated 250 attendees. Convened biannually ever since, the fourth NAF was held in Madison, Wisconsin, in April 2019 and was attended by 1,000 participants. The forum's continuing popularity is testament to the field's rapid growth; CPO's investment in the forum and the CRT have been factors that support this growth.

In addition to the above, it is anticipated that the development of a professional certification process through ASAP will grow the field of resilience service/adaptation providers, adding both jobs and revenue.

Examples of new career paths and types of jobs in the resilience space are set forth below. *Note that these are peripheral and anecdotal examples not directly linked to the CRT, and unless noted we have no direct evidence that these positions use or were influenced by the CRT or its presence.*

- Resilience officers and directors with private companies, particularly architectural and engineering firms, many of which are newly created positions:
    - *Janice Barnes, Principal and Director of Resilience with Waggonner & Ball.* She said she "loves the CRT" and uses it to perform work herself that she used to pay someone else to do. For example, she contracted Professor Katharine Hayhoe to perform needed climate downscaling for the Washington D.C. resilience report, but with the climate projections included in the Climate Explorer she no longer has to "hand roll" this type of work. This frees up funds to pay Professor Hayhoe to perform other value-added work and research.
    - *Katelyn Widness, Transportation and Community Resilience Planner with Kimley-Horn and Associates, Inc.* Kate facilitated the community resilience planning process for the City of Tallahassee in 2018, utilizing the CRT's Steps to Resilience to identify critical assets based on community values, quantify the exposure of those assets to a variety of threats, and perform geospatial analysis of vulnerabilities, linking environmental and socioeconomic data in new, dynamic ways. Kate is leveraging the Steps to Resilience and NEMAC partner FernLeaf Interactive's AccelAdapt software to acquire new business in other parts of Florida and the southeastern United States.
- Creation of new municipal resilience officers, with an investment by The Rockefeller Foundation's 100 Resilient Cities program. On July 8, 2019, The Rockefeller Foundation announced an $8 million commitment to continue supporting the work of Chief

Resilience Officers and member cities within the 100RC Network.[28] Feedback from some of these Resilience Officers indicates that they want, and need, additional training in the application of co-produced risk assessments based on a quantitative framework, such as the CRT's Steps to Resilience.

- Training and education for resilience-related jobs are being provided by several organizations, including:
    - The Association of Climate Change Officers (ACCO)
    - Antioch University's Center for Climate Preparedness and Community Resilience
    - The Security & Sustainability Forum

Assumption 3. Capacity building—standardization of the resilience process

Building capacity occurs at all scales, not just the local city scale. The standardization and digitization of applicable data feeds and the standardization of the resilience process create efficiencies that can be used by the growing resilience service provider market and individual resilience analysts.

The CRT, particularly its bespoke data tool the Climate Explorer and its concomitant data services, opens the climate services sector to medium and small players, allowing them to compete with large organizations such as The Weather Channel and Climate Central. Authors at Four Twenty Seven report that tools like the CRT and the Climate Explorer are useful for local governments, corporations, and financial institutions to "integrate into enterprise risk management, financial risk modeling processes, and capital planning."[29]

Training in the Steps to Resilience allows adaptation professionals to respond more nimbly in preparing proposals in response to requests issued by municipalities and other jurisdictions, i.e., their potential clients. A robust database detailing how much time and effort this approach has saved each of these municipalities does not exist, but from talking with staff in multiple cities it is likely there has been substantial time savings for each.

Assumption 4. Capacity building—reduction of future losses by resilience champions

The reduction of future losses by building a national community of resilience champions who are willing to take action may well be the largest value of NOAA and its entire climate products and services groups (including CPO's CRT and its engagement efforts), but it is also very

[28] The Rockefeller Foundation (July 8, 2019): The Rockefeller Foundation Launches New Climate and Resilience Initiative; Commits An Initial $8 Million To Continue Supporting Global Network Of Cities And Chief Resilience Officers.
[29] Gannon, Colin, and Nik Steinberg (2018): *Using Climate Data: A primer to inform the use of climate data in financial institutions, businesses and governments.* 427 Technical Brief. Berkeley, CA: Four Twenty Seven.

difficult to quantify. Thus, we have not assigned a benefit in our calculations. We see this as a potential major focus for any EIA analysis led by NOAA's Office of the Chief Economist.

Assumption 5. Additional economic indicators.

There are clear examples of best practices associated with investments in resilience, including those in governance and management oversight and accountability.[30] For example, in private companies where the CEO and/or management is responsible for a corporate resilience strategy, there are methods of evaluating progress toward the adoption of resilience practices, including a determination of where the company is along a trajectory towards developing and implementing innovative practices that transform industry resilience expectations. The approach for modeling progress in the private sector could lead toward a better calculation of investment in resilience.

Other economic factors to consider:

- Cities are increasing funding for engineering projects that actually build resilience (bond referendums, etc.).[31]
- Cities and engineering companies are hiring consultants to perform the aforementioned engineering work, leading to much larger engineering studies and multi-million-dollar investments in projects such as stormwater and transportation systems that take a resilience approach.[32]
- Esri and other companies are investing in resilience software and products, creating new markets and sales. Spin-off companies such as FernLeaf Interactive are filling this niche. The public-private partnerships supported by CPO and the Resilience Ecosystem are foundational to this growth. NEMAC+FernLeaf has influenced the resilience tools that Esri offers to customers.[33]

Note that the types of calculations listed above are beyond our expertise. We are framing this issue here, but recommend that further work be conducted by a group with greater expertise in economic analysis.

[30] Zamuda, Craig (2017): "U.S. Department of Energy Guidance on 'Cost-Benefit Analyses for Resilience Investments' and 'Resilient Utility Roadmap.'" Presentation at the 2017 Integrated Energy Policy Report (IEPR) Joint Agency Workshop on Climate Adaptation and Resilience for the Energy System, August 29, 2017.
[31] O'Connell, Laura, and Kyle Connors (April 2019): *Financing Climate Resilience: Funding and Financing Models for Building Green and Resilient Infrastructure in Florida*. Cambridge, MA: Harvard University, John F. Kennedy School of Government.
[32] *EBI Report 4800,* pp. 1-14, 1-15.
[33] Esri GeoNet blog: "New Version of NOAA Climate Explorer," posted June 1, 2018.

Alignment with published estimates

To test our logic and to better constrain our uncertainty, we have used the technique of benchmarking—common in business and advocated for in quality control processes such as Six Sigma Process Design—to compare our results to those obtained by other researchers or companies involved in this same business line.

The studies presented in the *Natural Hazard Mitigation Saves* reports finds the BCR for Mitigation (Resilience) Strategies have a range from 4:1 up to 11:1. Our findings are at the heart of this distribution, increasing our confidence in the results.

Benefit-Cost Analysis for Building Climate Resilience in the Southeast: Case Studies

The NEMAC team is witness to only a small portion of the national resilience landscape, and is a single point in what the publisher of the *Climate Change Business Journal* describes as the larger "U.S. climate change industry."[34] The numbers provided herein are therefore estimates based on our personal and institutional knowledge and our best ability to estimate, with a discussion of our methodology and possible error bars and uncertainty attendant with such estimates. As an applied research center, however, we believe that we have used the best economic data and methodology available to calculate these estimates. We encourage NOAA and other national stakeholders to recalculate and normalize the numbers provided herein when developing a national BCR for resilience.

Cost

To determine the estimated BCR for the CRT in the Southeast, we first calculate the "cost" as the amount of money that CPO has invested in NEMAC to create and support the CRT since its inception. This cost has been $1,125,000 for six years (from FY15 through FY20). As stated previously, there is no uncertainty associated with this number and we therefore believe it to be a good baseline number for the calculation.

TOTAL COST: $1,125,000

[34] *EBI Report 4800*.

Benefit

The numbers provided below are "benefit-to-date" numbers as of the time of this writing. As these cities wisely invest more dollars in resilience in the coming years, a greater benefit will be realized in the future. Because each of these cities has recently completed or is currently in the process of completing the assessment process and is in the process of implementing initial actions, there is little public or published information available about the assessments. Most of the numbers that follow are therefore estimates based on internal work by NEMAC+FernLeaf and discussions with municipal leaders. Due to confidentiality clauses in our contracts with each of these cities, we cannot provide more detailed assessment numbers at this time.

To calculate the "benefit," we sum the amount of estimated benefits outlined below, which are associated with investments made in projects related to NEMAC completed work. This benefit amount has greater uncertainty than the cost amount quoted above, but we estimate it to be at least $6 million, with a wide range of values due to uncertainty (see the detailed discussions for each section).

1.	Loss Avoidance—Losses and costs avoided	$4,730,000
2.	Capacity Building—Creation of jobs and career paths	$792,000
3.	Capacity Building—Standardization of the resilience process	$500,000
4.	Capacity Building—Reduction of future losses by resilience champions	$100,000
5.	Additional economic benefit (not valued due to current large uncertainty)	$0
	TOTAL BENEFIT	$6,122,000

The assumptions and rationale for each of these metrics are discussed more fully in the following sections.

Loss Avoidance—Losses and costs avoided

Estimated Benefit: $4.73 Million

The benefit calculated for this metric can be attributed to the CRT because the cities discussed below are directly following the CRT's Steps to Resilience framework. As previously pointed out, it is difficult—if not impossible—to separate benefits that may be attributable solely to the CRT from all economic activity associated with the resilience field.

The methodology used for this metric is most closely aligned with the National Institute of Building Sciences' *Natural Hazard Mitigation Saves* studies (2018, 2019) and the Global Commission on Adaptation's *Adapt Now* report (2019), previously cited. These studies examine the benefit of investing in a few primary areas: (1) early warning systems; (2) making new infrastructure more resilient (through building codes and ordinances); (3) making water resources and stormwater management more resilient; and (4) ensuring access to key facilities and corridors during and after hazard events. For each municipality with which NEMAC has worked, we primarily focus discussion on these four topics and estimate resilience benefits linked to those investments.

Asheville, North Carolina
Estimated To-Date Benefit: $1.98 million

The first calculation of interest is direct loss avoidance due to resilience efforts. This calculation is associated with lower uncertainty than the other cities presented below, as Asheville experienced an initial flood event with associated impacts in 2004 and another, comparable, flood in 2018 after resilience measures were undertaken and implemented.

Heavy precipitation events in 2004 led to flooding that caused $200 million in combined damages and losses, with almost half of this loss coming from lost tourism.[35] The impacts from this event led Asheville to undertake a proactive resilience-building approach. NEMAC began working with the local community on flood mitigation efforts in 2006; some of this work later became foundational when we collaborated with the CPO team in 2014 to develop the Steps to Resilience. We realized early on that there was no "road map" of best practices available for a diverse set of decision makers working across municipal boundaries to address these types of issues.

Following completion of the planning effort and the implementation by the city of several resilience activities, Asheville again experienced a series of very heavy rainfall events in May 2018, comparable to the amount of precipitation that fell in 2004. Comparison of the two events and the resulting amount of flood damage and its impacts can provide a comparable metric.

According to NOAA's Climate at a Glance tool, September 2004 monthly rainfall totalled 13.71 inches.[36] In May 2018, Asheville again experienced heavy precipitation events; Climate at a Glance documented monthly rainfall of 14.69 inches.[37] When examining the amount of rain and

[35] Boyle, John (2014): "From the archives: Impact of Frances, Ivan lingers years later," *Asheville Citizen-Times*. Published September 6, 2014, updated September 6, 2017.
[36] NOAA National Centers for Environmental information (2019): Climate at a Glance: City Mapping. Published October 2019, retrieved on November 5, 2019.
[37] Ibid.

its impact in Asheville, it's all about timing and location: the quantity of precipitation compared to the time frame during which it enters the watershed.

While flooding did occur in some of the same areas of the city in 2018 as it did in 2004, the combined damages and lost tourism from the 2018 flooding event is estimated to be only one percent of that resulting from the 2004 floods—or less than $2 million. Thus, Asheville's resilience investment over 14 years yielded an estimated benefit of up to $198 million: $200 million in losses compared to $2 million.

This number is supported using the methodology described in the introductory text to this section, with the following additional details:

- Early warning systems. After the 2004 flooding event, Asheville installed additional precipitation and stream gauges in the upper reaches of the watershed. Using data from these gauges during the 2018 precipitation event, water managers were able to increase the release of water from a dam upriver of Asheville at a steady rate over the course of six days. The water in the river ran bank-high during the event, but other than a short four-hour period it did not overflow into the business district. During the short window when the river overflowed its banks, the resultant flooding was only a few inches deep. As a result, there was very little business interruption in the primary business district that had experienced substantial commercial interruption during the 2004 event.

- Making new infrastructure more resilient. Asheville adopted new flood ordinances in 2010, which require new construction to be at least two feet above base flood elevation.[38] New buildings in Biltmore Village—the business district that experienced significant impacts during the 2004 flood event—were therefore designed to include considerable adaptive capacity and are not impacted by flooding. An additional economic benefit realized from Asheville's resilience-building efforts is its participation in the National Flood Insurance Program's Community Rating System, which has lowered flood insurance rates in Asheville by 10 percent.[39]

- Making water resources and stormwater management more resilient. Asheville prioritized the hardening of the dam that serves its primary water source and improvements to its water lines as the first priority option to build resilience. This action has already resulted in benefits.[40] The ability to contain and control very heavy rainfall that occurred in Spring 2019 was improved as a result.[41]

- Ensuring access to key facilities and corridors during and after hazard events. The key transportation corridor along U.S. Route 25, which runs through Asheville's Biltmore Village neighborhood, was elevated and its bridge over the Swannanoa River was

[38] Asheville, North Carolina Code of Ordinances: Chapter 7, Article XII, Section 7-12-1: Flood protection.
[39] City of Asheville, North Carolina: Public Works: Flood Information: Community Rating System Program.
[40] City of Asheville, North Carolina: Water: North Fork Dam Improvement Project.
[41] Shuler, Greg, City of Asheville Public Works Director. Personal communication with Jim Fox, 2019.

redesigned.[42] This corridor is one of two main access points to Asheville's hospital and the downtown business district, and has remained open during heavy rain events subsequent to its redesign.

To assign a normal probability distribution to this amount of benefit, we can find a mean with one standard deviation to give us values of $31.30, $99.00, and $130.30.

For the second part of the uncertainty calculation, we assume that only a small percentage of this amount should be attributed to the CRT. In 2014, to ensure that the CRT was used by local planners, we partnered with the Southeast Sustainability Directors Network (SSDN) to facilitate a series of workshops for 10 cities across the Southeast, with a goal of developing local adaptation plans.[43] Asheville was among these cities, and we worked closely with Asheville city staff in this process during 2014 and 2015. In 2016, the City of Asheville was, to our knowledge, the first municipality to use the Steps to Resilience to develop a Climate Resilience Plan,[44] which was adopted as Appendix D to its Comprehensive Plan.[45]

We assume a one, two, or five percent benefit attributed to the CRT. Cross-multiplying with the above distribution, we calculate a range of benefits from $0.3 million to $6.5 million, with a mean of $1.98 million. For this case study, we use the mean for the calculation.

Charleston, South Carolina
Estimated To-Date Benefit: $2 million

Charleston's leadership has invested a great deal of time and energy in building resilience, likely because the city is already experiencing fairly severe impacts from a changing climate. City leaders are focusing on what to do *now,* rather than what to do some time in the future.

In July 2014, Mark Wilbert—now Charleston's Chief Resilience Officer—was just two weeks into his job as Charleston's Emergency Manager. The city's Sustainability Director asked him to attend the first Southeast Sustainability Directors Network (SSDN) workshop that

> *"There's little doubt that storms are becoming more intense. This is not just about sea level rise, but change in the weather. The ground can't absorb the rain events we are getting."*
>
> — Mark Wilbert
> Chief Resilience Officer
> Charleston, South Carolina

[42] ABC Project Database: Bridge Summary Sheet: 2010 - Biltmore Avenue Bridge. Accelerated Bridge Construction University Transportation Center, Florida International University.
[43] Southeast Sustainability Directors Network: Partnership for Resilience and Planning (PREP).
[44] City of Asheville, North Carolina: Sustainability: Climate Resilience.
[45] City of Asheville (2019): Planning and Urban Design: Comprehensive Plan. Updated June 19, 2019.

NEMAC was hosting in Asheville using the CRT's Steps to Resilience. Like Asheville (described above), Charleston was one of 10 cities across the Southeast working to test the CRT's Steps to Resilience and their applicability for local municipalities.[46]

In September 2016, Wilbert presented on Charleston's resilience work at the Carolinas Climate Resilience Conference held in Charlotte, North Carolina. Charleston's planning efforts had resulted in over 80 options to address resilience—but with no prioritization method or roadmap forward. City leadership was unclear which of the identified options would be most effective within their financial and other constraints. After a visit by Wilbert and his team to our offices in Asheville, we began discussions with them about using the Steps to Resilience process as a framework to continue Charleston's resilience-building efforts.

In 2018, the City of Charleston released a Request for Proposals (RFP) for a Vulnerability and Risk Assessment.[47] The RFP specifically referenced the use of the Steps to Resilience process, and the work was awarded to NEMAC+FernLeaf in early 2019. The study was completed in January 2020.

Using the CRT's Steps to Resilience framework and undertaking a quantified assessment, city leadership is focusing on actions in Charleston's historic Peninsula area. Already, members of Charleston's City Council have been able to better understand the critical nature of some of the key investments required. Charleston Mayor John J. Tecklenburg has stated, "we simply must make flooding and drainage our city's top long-range priority."[48]

To assign a benefit to Charleston's resilience efforts, we estimate a baseline benefit with the potential for realization of a much higher number over the next few years. The CRT-based report integrates with the city's Flooding and Sea Level Rise Strategy, the Dutch Dialogues, and other planning efforts, multiplying the realized benefits. The benefits are supported using the methodology described in the section above, with the following additional details:

- Early warning systems. Charleston staff have worked with NOAA's Office for Coastal Management and the local National Weather Service office to improve early warning systems. Although these systems are still not perfect, there has been a tremendous improvement in the data they provide. Given that the number of tidal events that cause Charleston to close streets increased from 38 days in 2015 to over 50 days in 2016,[49] any improvement in data provided by these systems is crucial. We cannot assign any benefit value from these improvements to NEMAC's work with the city; however, this value should be included in calculations of benefit should NOAA expand the scope of this study.

- Making new infrastructure more resilient. Charleston leadership has designated this topic as one of the most important issues for them to address. Charleston is

[46] Southeast Sustainability Directors Network: Partnership for Resilience and Planning (PREP).
[47] City of Charleston Proposal Number 18-P037R, Consultant to provide Vulnerability Assessment Services.
[48] Darlington, Abigail (2019): "Charleston Mayor John Tecklenburg puts flooding at top of priority list in State of the City speech," *Charleston Post and Courier.* Published January 23, 2019.
[49] Behre, Robert (2018): "Sunny day flooding could soon be history in Charleston as new valves hold back highest tides," *Charleston Post and Courier*. Published February 9, 2018.

experiencing significant growth and development; unfortunately, much of this growth is occurring in high-hazard areas. Until leadership undertook the risk assessment using the Steps to Resilience and assessment software developed by FernLeaf Interactive, it did not have quantified information to present to the Charleston City Council. Armed with the quantified data coming from the assessment, a realistic conversation has begun. We have not assigned a benefit value to this metric, but believe that significant value will be realized in coming years.

- Making water resources and stormwater management more resilient. One of the primary outcomes of the Steps to Resilience framework is the ability to prioritize options: which should be implemented now, and which later? Charleston is already realizing benefits from this metric. As a result of the vulnerability and risk assessment, it was apparent that efforts to build resilience on the Peninsula, Charleston's historic district, would result in the highest level of socioeconomic benefit. Charleston has been installing tidal check valves to limit "sunny day" flooding from tidal events.[50] The resilience assessment finds that not only key commercial and residential districts are being protected by this action, but also historic churches and public housing. The ongoing resilience assessment calculates a value of almost $2 million for just one of these projects, based on the value of property protected from frequent flooding; several such projects are being installed on the Peninsula.

- Ensuring access to key facilities and corridors during and after hazard events. Prior to undertaking the assessment, Charleston leadership was focused on the topic of sea level rise. By working through the Steps to Resilience framework, they recognized as an immediate "pain point" the restriction in and to the city's main transportation corridors as a result of flooding. Over the course of the past year while the quantified assessment has been ongoing, leadership is realizing that access to transportation corridors is actually one of the most important issues to be addressed. This will take several years to resolve, so we have not attributed any benefit value in our calculation—but we believe that the benefit will eventually be substantial.

For the benefit calculation, the true benefit comes from assisting Charleston with a strategic focus on what is most important to invest in now based on limited resources. In the presentation of results to Charleston's City Council in January 2020, the following points were made: "*Limited resources means that every issue cannot be addressed. Three types of risks will require planning for today and additional stakeholders to address: near-term focus on Flooding, Tidal Flooding (with current sea level rise), and Hazardous Materials; long-term investment in future change related to Sea Level Rise, Future Tidal Flooding, and Extreme Heat; and, finally, prepare for the high-impact events of a direct hit from a Category 3 storm and related Storm Surge or a significant Earthquake.*"

Based on these priorities, Wilbert estimates that city infrastructure projects alone could top $1 billion over the next 20 to 40 years. Of this, a seawall along Charleston's Battery could cost

[50] Ibid.

$100 million and take 10 years to complete. The city is investing over $10 million per year in downtown stormwater projects, and has increased its budget to address so-called nuisance flooding from $8 million to $12 million a year.

Because Charleston has heavily used the CRT to better prioritize its investments, we assume the mean value of two percent over the next five-year period. Using the numbers discussed above, the city has invested/will invest an estimate of $100 million in resilience during this period. We therefore calculate the CRT benefit to be two percent of $100 million—or $2 million—with a possible range of $1 million to $5 million.

West Palm Beach, Florida

Estimated To-Date Benefit: $500,000

West Palm Beach finished its assessment process in early 2020 and we estimate that it has realized a benefit by properly prioritizing its projects pursuant to Step Four of the CRT's Steps to Resilience.

> *"By including staff from across our city departments, we now have increased understanding of the issues as well as the knowledge and analysis we need to align resilience in our daily operations. We are now much better prepared to make the most effective and equitable application of the dollars we are investing in resilience."*
>
> — Penni Redford
> Sustainability Manager
> City of West Palm Beach

Using the Steps to Resilience in its resilience assessment and planning, the City of West Palm Beach is refocusing dollars it had previously planned to invest primarily in seawalls. Instead, city leadership has prioritized a greater investment in upgrading the city's stormwater and water supply system.[51,52,53] While this work is in progress, we estimate that the benefit value for more focused investments is equivalent to $500,000. This number should be calculated more precisely by the city as it moves forward, but we believe that this number is a good beginning estimate for purposes of this paper.

- Early warning systems. There are no such projects in West Palm Beach.
- Making new infrastructure more resilient. West Palm Beach enacted an ordinance that required increases to base flood elevation prior to the initiation of the climate resilience assessment, so we have assigned no benefit value to this metric.

[51] Palm Beach Post Editorial Board (2019): "Editorial: Palm Beach County's cities, towns taking the initiative on sea-level rise threat," *The Invading Sea: Can South Florida be Saved?* Published July 28, 2019.
[52] The Resilience Journal (2018): West Palm Beach at the EarthX Resilient Cities Symposium. Interview of Mayor Jeri Muoio and Sustainability Manager Penni Redford by The Resilience Journal Editor Alex Díaz. YouTube video published June 2, 2018. A discussion of the city's climate resilience assessment begins at 18:10.
[53] Transformative Actions Program: "City of West Palm Beach Climate Vulnerability Analysis."

- Making water resources and stormwater management more resilient. West Palm Beach has an asset that is rare in South Florida: the Grassy Waters Reservoir, a surface water source. In contrast, most communities in South Florida rely on wells drilled into shallow aquifers—aquifers that are in danger of compromise by salt water due to sea level rise. Prioritizing this reservoir and its supply points assures continued viability of this key asset. The final plan has not been publicly released, but one of the top prioritized recommendations under the Climate Impacts on Water Supply category is to ensure that a new drought plan includes the right numbers for a scenario that includes increased population levels and the likelihood of future drought. In addition, planned improvements to the city's Stormwater Master Plan that were identified during the climate resilience assessment were highly prioritized, with an additional focus on social equity for near-term implementation.
- Ensuring access to key facilities and corridors during and after hazard events. Corridors along the Atlantic Intracoastal Waterway and their importance to commerce and business are very important to the local economy. Perhaps even more important are points of access to local hospitals—in fact, one hospital has to be evacuated before major storms because storm surge restricts access to the main parking area and emergency room entrance.

The city collects a one-cent sales tax to support resilience projects, and this money is added to other revenue for resilience projects. Water supply upgrades have an estimated benefit value of $125,000. Ongoing planned improvements to the city's Stormwater Master Plan identified during the climate resilience assessment were highly prioritized and are estimated to save city residents almost $6 million per year.

Because West Palm Beach, like Charleston, has relied heavily on the CRT to reprioritize its investments from sea level rise protection to an increased focus on stormwater projects and water supply issues, we assume the mean value of two percent over the next five-year period. Using the numbers discussed above, the city has invested/will invest an estimate of $25 million in resilience during this period. Therefore, we calculate the CRT benefit as two percent of $25 million, or $500,000, with a possible range from $250,000 to $1.25 million.

Tallahassee, Florida
Estimated To-Date Benefit: $250,000

Tallahassee, Florida's capital, was experiencing a string of hazards impacting the city, but city leadership was having trouble getting started with resilience planning. In 2017, the city issued an RFP to develop a community resilience plan, stating that they were looking for a team with national expertise and local knowledge. NEMAC+FernLeaf partnered with Kimley Horn, one of the nation's premier planning and design consultants, to provide the solution.

City leadership recognized the importance of using the CRT's Steps to Resilience process, but they also were seeking a web-based tool that would update with new information as it became available and a local engineering firm to provide in-person services. The planning team worked with city leadership in 2018 and 2019 to provide a complete resilience assessment, working through the Steps to Resilience to Step Four: Prioritize & Plan.[54] Tallahassee is just beginning to move into Step Five: Take Action.

We do not include a detailed case study for Tallahassee herein, given that the city is similar in size to the aforementioned examples. We estimate a benefit value of $250,000.

State of North Carolina and Two Regional Planning Councils
No attributed value

In addition to the four municipalities discussed above, NEMAC has conducted climate resilience assessment and planning projects with two regional Councils of Government (COGs) in the State of North Carolina and worked with the State of North Carolina as it developed its Climate Risk Assessment and Resilience Plan (released in June 2020). We know that a benefit will be realized from this work, but we do not feel that it can yet be quantified. We therefore provide no benefit estimate.

Capacity Building—Creation of jobs and career paths
Estimated Benefit: $792,000

This benefit is calculated by multiplying the number of jobs created by the annual salary per job, as discussed in more detail below; however, we attribute only a percentage of this benefit to the CRT. As stated previously, there is some uncertainty in the exact percentage calculation provided here.

[54] City of Tallahassee, Florida: Public Safety: Tallahassee Community Resilience Plan.

NEMAC+FernLeaf
Estimated Benefit: $292,000

Including positions created for both staff and student interns, we estimate a benefit of $292,000 attributable to the projects that have used CRT's Steps to Resilience risk assessment framework. The NEMAC team has been actively working with NOAA since 2010. During that time, we have leveraged the partnership to obtain new revenue streams and to create a private spin-off—FernLeaf Interactive—and a public-private partnership known as NEMAC+FernLeaf. In 2018, NEMAC+FernLeaf had total joint revenue of about $1.6 million. Note, however, that this amount includes revenue unrelated to resilience projects.

The metrics arising from this activity include (i) number and value of projects awarded to/received by NEMAC or NEMAC+FernLeaf, and (ii) associated job creation. This information is included in the tables below.

	Project/Municipality Name	Total Contract Cost*	Cost Share / Additional Effort Expended	Total Value of Project
1	Asheville, North Carolina	$ 58,000	$52,000	$110,000
2	Charleston, South Carolina	$195,000	ongoing	$195,000
3	Tallahassee, Florida	$285,000	$ 0	$285,000
4	Triangle region, North Carolina	$100,000	$115,000	$215,000
5	West Palm Beach, Florida	$200,000	$ 0	$200,000
	TOTAL			$1,005,000

** Project cost is tied to the size of the municipality and the list of services provided.*

In addition to the projects listed in the table above, NEMAC has and continues to receive funding from the National Fish and Wildlife Foundation to perform a coastal exposure analysis for the United States. This work is tied to the CRT's Steps to Resilience as a Step One: Explore Hazards exercise. We estimate that approximately 10 percent of this revenue for the period FY2015 through FY2020—or approximately $112,500—is attributable to the CRT. NEMAC has also performed 3D GIS visualization work as a subcontractor to Hazen and Sawyer for the City of Fort Lauderdale, Florida. This work can be tied to Step 1 and Step 4 of the CRT's Steps to Resilience. We estimate that $50,000 of this revenue is attributable to the CRT.

The total revenue to NEMAC+FernLeaf from work related to the CRT described above totals $1,167,500—a number larger than the NOAA CPO investment in NEMAC for its work on the CRT ($1,125,000). Value, therefore, has been created in the jobs related to this revenue stream.

To calculate that value, we look at an estimation of job creation. We estimate that the following jobs/career paths have been created through NEMAC and NEMAC+FernLeaf since 2014:

Title	Estimated Annual Salary	FTE – % of Job Related to Resilience	# of Positions Created	Total
Lead Resilience Analyst	$105,000	.3	1	$31,500
Resilience Analyst	$75,000	.5	2	$75,000
Project Manager	$75,000	.5	1	$37,500
Operations Manager	$75,000	.3	1	$22,500
AccelAdapt Tech	$45,000	.8	1	$36,000
Editor	$60,000	.6	1	$36,000
Designer	$45,000	.3	1	$13,500
GIS Analyst	$55,000	.3	2	$33,000
Programmer	$55,000	.3	2	$33,000
Total				$318,000

In addition to staff, NEMAC and FernLeaf have hired numerous students in paid internships for work relating to both the CRT and the resilience planning projects discussed in the previous section. Many of these students have since graduated, and some now hold positions in the resilience field.

Calculating the benefit of job and career positions created through NEMAC and FernLeaf and attributing benefit to the CRT is difficult; we therefore attribute only a percentage of this benefit herein. We do not believe that we can, in good faith, attribute both the project revenue and the jobs added as separate benefit metrics, as they are intrinsically linked and the addition of the value amounts would be counting the same benefit twice. We therefore attribute 25% of the project revenue to this benefit metric, assuming that this number includes the benefit of the student and intern job creation: $1,167,500 × .25 = $292,000.

New municipal positions for resilience officers
Estimated Benefit: **$500,000**

We see that cities are beginning to realize the importance of these positions to be able to lead the increasing amount of effort required to build resilience. We estimate that the creation of these jobs has yielded an economic impact related to the CRT of $500,000. This number is calculated using a "man-year equivalent" for this type of position, which includes both salary and benefits, then multiplying by four to represent the number of new municipal resilience

officer positions of which we are personally aware ($125,000 × 4 = $500,000). To our knowledge, four cities with which NEMAC+FernLeaf has worked have created resilience officer positions:

- Community Resilience Officer: Chapel Hill, North Carolina
- Chief Resilience Officer: Charleston, South Carolina
- Chief Resilience Officer: Tallahassee, Florida
- Chief Sustainability Officer: West Palm Beach, Florida (who was also named Resilience Officer in late 2018)

Capacity Building—Standardization of the resilience process
"Most likely" estimated benefit: $500,000

This benefit represents an estimate of the amount saved by communities, consultants, and others due to the availability of streamlined climate information and data feeds via the CRT and the Climate Explorer. Such information and data are used in preparing RFPs and conducting local resilience planning. Prior to the creation of the CRT and the Climate Explorer, many—or even most—communities would have subcontracted with high-cost consultants for the assimilation, synthesis, and calculation of climate information and data.

We believe that this may be the largest category of potential benefit, but it also bears the greatest amount of uncertainty; we therefore assign a "most likely" benefit value at the current time. This number is derived from the methodology described below.

Climate Explorer user savings
Estimated Benefit: $150,000

After a cursory review, we estimate that approximately 100 individuals have contacted the CRT editorial team via email since the site's launch with notes or questions about the use of data served by the Climate Explorer, serving as a small subsample of total Climate Explorer users. We assign a benefit value of $1,500 per user representing cost savings realized from access to streamlined data services through the Climate Explorer, resulting in an estimated benefit of $150,000 for this metric.

NEMAC+FernLeaf software development
Estimated Benefit: $100,000

NEMAC+FernLeaf has created an automated process, some of which is available as open-source code for the Climate Explorer, that saves people from having to work through the Steps to Resilience by hand, allowing an analyst to spend more time interpreting—rather than creating—the data. This "disruptor" technology provides climate information at a very local

scale, changing the value proposition in the marketplace.

The process has the potential to greatly expand the market, as it makes the resilience process much more affordable for small and medium-size cities—ultimately growing more resilience at a national scale and generating an enormous cost savings nationwide for losses and costs avoided. We assign this metric an estimated benefit of $100,000.

"Train the Trainer" workshops
Estimated Benefit: $200,000

Over the past four years, NEMAC has partnered with other members of the NOAA CRT team to create content and offer workshops in the use of the CRT, the Climate Explorer, and the Steps to Resilience. Primary partners in this endeavor include the Association of Climate Change Officers (ACCO), the Southeast Sustainability Directors Network (SSDN), the National Adaptation Forum, and The Collider in Asheville, North Carolina. We estimate that we have reached over 1,000 people through these trainings. Assuming that each attendee has on average obtained at least $200 in benefit from properly applying resilience techniques in his or her work, we calculate a total benefit value for this metric of $200,000.

Additionally, members of the NEMAC and CRT teams worked with the State of North Carolina to develop its State Risk Assessment and Resilience Plan using the Steps to Resilience and other content from the CRT. A central goal of this project was the ability to scale content from the state level down to regional councils of government and finally down to local municipalities. We believe that this work will greatly increase the benefit amount assigned above; however, as this work is very recent, we have not yet assigned any benefit value.

The Resilience Ecosystem
Estimated Benefit: $50,000

In addition to the above, we note that members of the Resilience Ecosystem—public, private, and non-government organizations loosely related by profession, some of which have been provided seed funding through NOAA CPO and Climate Resilience Fund grant opportunities—are providing templates, automated data feeds, and other similar tools that allow adaptation professionals to spend more time providing climate services rather than generating basic frameworks or climate data feeds.[55]

Organizations such as Azavea and Headwaters Economics have received such funding this fiscal year for projects that are directly linked to expanding the data provided by the Climate

[55] EcoAdapt: Resilience Ecosystem Workshop.

Explorer. We assign a small benefit value of $50,000 to this metric, but anticipate that this number will grow over the next several years.

Capacity Building—Reduction of future losses by resilience champions
Estimated benefit: $100,000

Through numerous presentations, workshops, and webinars, NEMAC supports the CRT in growing local champions who are driving resilience across the nation, with particular focus on the southeastern United States. Through our relationships with the SSDN network, the Carolinas Climate Resilience Conferences, the American Planning Association, and a variety of others, we estimate that there are over 100 new resilience champions in this region. These champions know that they have in the CRT an effective toolkit and resilience process; perhaps more importantly, they know that they have a growing network of fellow professionals on whom they can rely. This metric is very difficult to assess, so we conservatively assign a value of one "man-year" equivalent, or $100,000.

Additional economic indicators
No attributed value

The additional economic indicators discussed in the Primary Value Metrics for Benefit section are not directly linked to NEMAC funding; therefore we do not assign a benefit value herein. We do believe, however, that benefit is already being realized and should be captured by NOAA in a subsequent national economic impact analysis.

Recommended Next Steps

In total, we attribute to the CRT a BCR of 5.44, with more upside possible in coming years.

In January 2020, NEMAC completed a revised version of this analysis and recommended that NOAA leadership consider the following options when moving forward with this type of analysis:

- Verify that BCR is the right economic metric for these types of analyses.
- Determine whether or not, and how, to expand the scope of this study to investigate and calculate similar findings on a national scale.

Examining a larger group of case studies would advance resilience activities nationwide.

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