Beyond One Bad Day: Exploring social, economic, and environmental co-benefits of resilience in the National Disaster Resilience Competition

By

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Abstract

Despite the rise in extreme weather events, communities in the U.S. tend to underinvest in disaster risk management and resilience efforts. This is due in part to prohibitively high costs, which are not justified by the traditional method of determining the benefits of such investment. The benefits of resilience are often unclear, distant, and limited to a narrow understanding of a project's impact. Infrastructure and program investments can offer social, economic, and environmental co-benefits that extend beyond a project's disaster risk reduction and help to meet community needs every day, not just during the rare occurrence of a disaster. Decision-makers need a way to incorporate co-benefits into the evaluation of these investments. However, a standard methodology to assess quantitative and qualitative value of community resilience co-benefits does not exist.

The Department of Housing and Development offered a way to resolve the current disconnect between project costs and benefits in a novel requirement for the one-time National Disaster Resilience Competition (NDRC) of 2014-2015. The NDRC required forty U.S. state, county, and city applicants to develop a qualitative benefit-cost analysis (BCA), encouraging consideration of the hard-to-quantify benefits.

This thesis analyzes the perception of social, economic, and environmental co-benefits by these communities as reported through the competition BCAs. It examines which co-benefits were identified across proposals and to what extent assessment methodologies were applied to quantify them. The findings and recommendations in this thesis build the foundation of a standard framework for resilience co-benefits. Through adaption of the traditional BCA model, decision-makers will ultimately be empowered to strengthen the case for resilience investment in their communities.

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List of Acronyms

Acronym	Name
BCA	Benefit-cost analysis
BCAR	FEMA Cost-Benefit Analysis Re-Engineering Guidance
BCR	Benefit-Cost Ratio
BLS	Bureau of Labor Statistics
CDBG	Community Development Block Grant
CDBG-DR	Community Development Block Grant Disaster Recovery Program
DOT	U.S. Department of Transportation
DRM	Disaster risk management
EPA	Environmental Protection Agency
ESG	Environmental, social, and corporate governance
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
HEC-FIA	USACE Hydrologic Engineering Center's Flood Impact Analysis
HMGP	FEMA's Hazard Mitigation Grant Program
HUD	U.S. Department of Housing and Urban Development
IPCC	Intergovernmental Panel for Climate Change
NDRC	National Disaster Resilience Competition
NOAA	National Oceanic and Atmospheric Administration
NOFA	Notice of Funding Availability
NPV	Net present value
OMB	U.S. Office of Management and Budget
SOVI index	Social Vulnerability Index
UNISDR	United Nations Office for Disaster Risk Reduction
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
WHO	World Health Organization
WHO HEAT	World Health Organization Health Economic Assessment Tool

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Section 1: Introduction

1.1 Rising Disaster Risks and Costs

Between 1980 and 2017, 219 weather and climate disasters that each caused over $1 billion in damages struck the U.S. (NOAA National Centers for Environmental Information 2018). Last year alone, sixteen of these disasters struck varied geographies in the U.S. in the form of severe storms, drought and heatwave, tornados, firestorms, flooding, and freeze (see Figure 1). These events set a new annual record in the U.S. for the cost of weather and climate disasters, totaling $306.2 billion in economic losses (NOAA National Centers for Environmental Information 2018). These events damage more than just physical infrastructure and properties, and have long-lasting effects on the environment, community health and wellbeing, and the local and regional economy. Over a decade after Hurricane Katrina, for example, parts of New Orleans are still recovering.

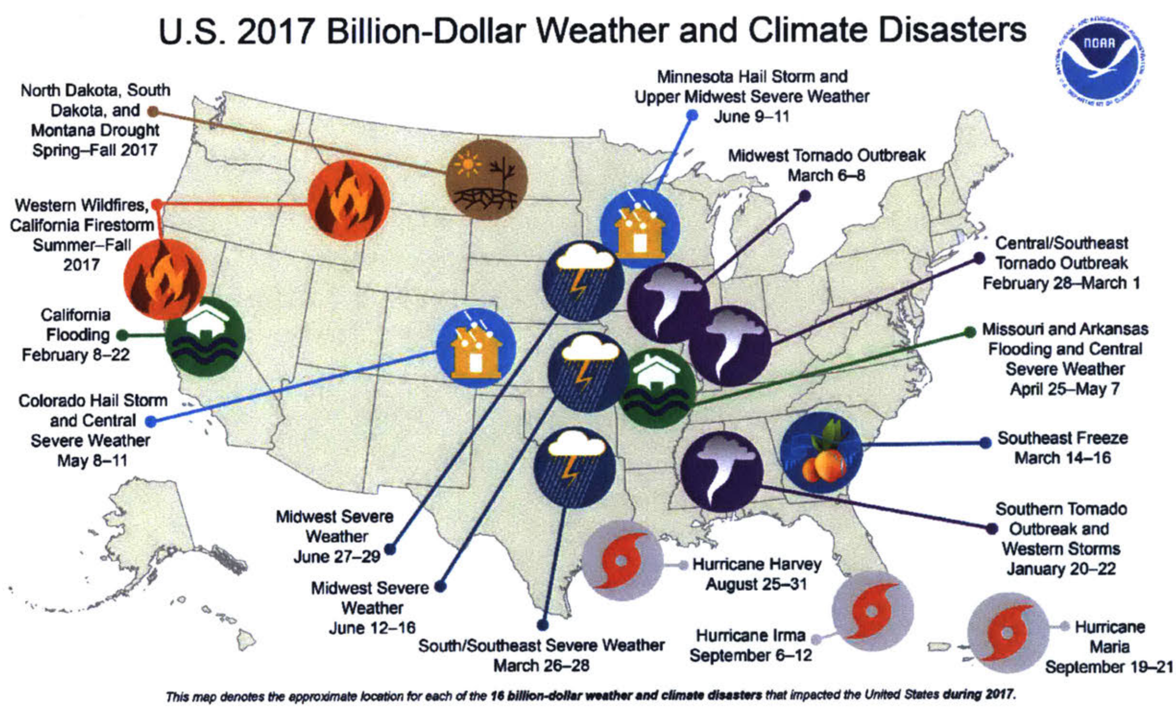

Figure 1. Sixteen weather and climate events resulting in over $1 billion of economic losses in the U.S. in 2017. Source: NOAA National Centers for Environmental Information 2018.

Climate change threatens to exacerbate the toll of disaster on communities. At the current rate of emissions, scientists believe that the continued accumulation of greenhouse gases in the atmosphere will drive a series of disruptive and extreme climatic events in communities around the world (Stocker 2014).

In short, disasters are expensive and government spending on disaster is only expected to increase. Yet expenditures on prevention are almost always lower than those on disaster response; on average, $1 is spent on disaster risk reduction for every $7 spent on disaster relief (J. Kellett and Caravani 2013). Between 2011 and 2013, the federal government spent $136 billion on disaster relief, allocated through agencies such as the Federal Emergency Management Agency (FEMA) and U.S.

Department of Housing and Urban Development (HUD). In response, federal agencies have recently begun to encourage investment in interventions that improve community resilience to mitigate the risk and impact of disasters.

1.2 Co-benefits of Resilience Investment and the Benefit-Cost Analysis

Resilience refers to the "ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions" (UNISDR 2009). Essentially, resilience is the ability of a community to withstand and recover from the shock of a natural disaster. While an investment in resilience is primarily intended to protect against rare but catastrophic disasters, such as a 1000-year flood, Category 6 hurricane, or a far-reaching wildfire, the same projects can provide benefits that improve the daily life of community members. These secondary benefits, or co-benefits, can build interest and support for resilience projects, and give weight to externalities that do not easily translate into a disaster cost estimate.

While interventions that improve community resilience are increasingly considered a necessary means to maintain community and economic stability, policymakers still "tend to underinvest or not invest at all" in projects that reduce disaster risk, partially due to the fact that the costs of resilience investment are "visible and immediate whereas the direct benefits of such investments, and indeed the distribution of these benefits, are unclear and distant" (Vorhies and Wilkinson 2016). The conversation around disaster risk management (DRM) is just beginning to shift. Instead of a "gamble" (Tanner et al. 2016) that only pays off in the rare—and, in communities with no history of extreme events, unfathomable—disaster, investment in DRM can be framed as a no-regrets action through a strong business case that incorporates the positive externalities of resilience interventions.

For large expenditures, funders prefer to see evidence-based practices that ensure a sound financial investment. Infrastructure projects are typically weighed using a benefit-cost analysis (BCA), a method by which the future benefits of a project are determined and compared to cost of its construction, operations, and maintenance. When benefits exceed the cost, a project is more likely to gain approval. A project is cost-effective when the present value of project net benefits divided by its costs results in a Benefit-Cost Ratio (BCR) of 1.0 or greater (FEMA 2009):

$$\frac{net\ benefits}{net\ costs} > 1.0$$

In order to build the business case to support resilience investment, there is a need to reframe the way in which future benefits of a project are accounted. The BCA has historically been limited in its ability to reflect the full costs and benefits of a project. When a project is intended to address a one-in-100-year storm, the process of convincing decision-makers to spend limited resources becomes complex. A disaster may never occur; meanwhile, communities have more immediate funding needs. Resilience benefits alone may not balance the costs of implementation and maintenance. The full value of these projects are implied, inferred, and typically unquantified. For this reason, proposals for resilience projects often fall short in a list of community priorities, and the true cost of a disaster is hidden until it is too late.

With this in mind, HUD developed a new way to account for the intangible co-benefits of resilience by developing a new model of BCA for its 2014-2015 National Disaster Resilience Competition (NDRC) (further described in Section 2). This BCA required competition applicants to identify qualitative and quantitative co-benefits across four benefit categories: Resiliency Value, Environmental Value, Community Development Value, and Economic Revitalization Value. The competition applicants were the trailblazers of a new method that has the potential to inform a new type of evidence-based practice.

1.3 Research Questions and Contents

This thesis analyzes the perception of social, economic, and environmental co-benefits by communities participating in the NDRC as reported through the competition BCAs. Using data from 28 proposals, this thesis examines which co-benefits were identified and the extent to which assessment methodologies were applied to quantify them.

This research uses the universe of data provided by the NDRC to understand what communities mean when resilience co-benefits and what means they have to evaluate them. Given the prompt by HUD, which co-benefits did communities identify? To what extent were they able to apply assessment methodologies to quantify the value of the co-benefits? Using this unique opportunity to better understand how municipalities and counties value these typically soft benefits of resilience, this thesis examines the reported benefits for proposed projects of 28 out of the 40 NDRC finalists (13 winners and 15 unfunded finalists) and analyzes the extent to which co-benefits were identified and quantified. By identifying patterns and conflicts, I reveal the challenges behind adoption of this expanded BCA.

Through semi-structured interviews, I also seek to draw out the contextual information that explains the approaches for how applicant teams developed their applications and assessed resilience co-benefits.

The analysis and interviews lead to policy recommendations for proposing a framework and a discussion of the future of the expanded BCA. The findings from this thesis can help decision-makers better understand the range of benefits—both direct benefits and co-benefits—of a resilience investment and can help policy makers define a framework that can be used to communicate the full value of resilience more broadly to a wider audience of stakeholders.

This thesis is structured as follows:

Section 2: Context – This section introduces the case study and provides background information on the BCA used in the NDRC. This information is supported by an interview with the mastermind of this BCA model from HUD to learn the impetus for the new approach and process of creating the simple framework template.

Section 3: Literature review – I examine the relevant background literature about the BCA with relation to risk reduction, resilience, and climate change adaptation, identifying common parameters taken into consideration as well as limitations of the application of the BCA. I also present an overview of the current academic understanding of co-benefits.

Section 4: Methods – This section summarizes the methodology and data used for this study: 1) a qualitative analysis of the required BCA Narrative Table in the NDRC Phase 2 applications and 2) semi-structured interviews with funded and unfunded NDRC finalists to understand their process for the BCA.

Section 5: Findings & Discussion – This section frames the key findings that emerged from the BCA crosswalk and interviews. I analyze the inclusion and quantification of environmental, community development, and economic revitalization co-benefits across applications. This analysis presents the range of benefits considered across resilience interventions in geographies recovering from disasters, and the data used to justify their inclusion. These findings lead to a discussion of 1) the challenges associated with this structure and 2) the gaps in data and literature regarding the ways in which co-benefits can be quantified or otherwise accounted for. I discuss the tradeoffs of standardization and discretion in BCAs, and the implications of a more flexible system on the process of designing and evaluating projects.

Section 6: Recommendations and Looking Ahead – This section proposes steps that federal agencies, the private sector, and communities can take to build toward a more standardized consideration of co-benefits. This section also looks ahead to the future of resilience co-benefit valuation through BCA.

Finally, the **References** list the academic literature, tools, guidance, and articles cited in the body of this thesis. **Appendices** include the full BCA crosswalk of the Phase 2 NDRC applications, a list of declared disasters that made counties and states eligible for the competition, funding allocations, and the interview guide for semi-structured interviews.

Section 2: Context

2.1 HUD National Disaster Resilience Competition (NDRC)

While the U.S. Department of Housing and Urban Development (HUD) has not historically been at the forefront of disaster recovery, the evolution of HUD priorities to include resilience has occurred naturally. HUD's mission is to create strong, sustainable, inclusive communities and quality affordable homes for all (HUD n.d.), and resilience is increasingly important as the impacts of extreme events grow in scale and cost to society.

Since Hurricane Katrina in 2005, Congress has appropriated funds to HUD to help communities with unmet disaster recovery needs as part of the funds through the Community Development Block Grant (CDBG) Disaster Recovery (CDBG-DR) Program. HUD would then allocate the funds to the most impacted and distressed areas for disaster relief, long-term recovery, infrastructure restoration, housing, and economic revitalization (HUD n.d.). Compared to FEMA's Hazard Mitigation Grant Program (HMGP), the CDBG-DR grants are flexible in their application beyond traditional repair of damaged properties and infrastructure, and can be used to advocate for equity through special economic development activities, microenterprise assistance, and planning and capacity building (HUD 2001).

When Hurricane Sandy struck the northeast coast in late 2012, the storm damages were the most costly on record (until surpassed by hurricanes Harvey and Maria in 2017). In response, Congress appropriated $60 billion to federal relief agencies through the Disaster Relief Appropriations Act, 2013 (PL 113-2), the single largest appropriation of disaster recovery funds in U.S. history. While the funds were primarily intended for recovery of the New York and New Jersey area following Hurricane Sandy, the funds could also be used for other Presidentially Declared Disasters from 2011 to 2013. With approximately $15.2 billion in unspent funds, HUD used a FEMA formula to allocate most of the funds to the areas that were most impacted and distressed by other disasters.

Figure 2. Residents of Breezy Point, NY, returning to their homes after Hurricane Sandy. Source: Anthony DelMundo for New York Daily News.

With the remaining $1 billion in funds, HUD embarked on a "transformative effort to rethink the way disaster recovery dollars are spent" (HUD 2016). Jessie Handforth Kome, Deputy Director of the Office of Block Grant Assistance in the Office of Community Planning and Development at HUD, was assigned to write the framework for a competition to award funds in 2013. In my March 2018 interview with Ms. Kome, she described how the competition came together. The Secretary of HUD at the time, Shaun Donovan, proposed a new idea to the executive Office of Management and Budget (OMB) and other federal agencies. Instead of allocating the remaining $1 billion by formula, HUD could allocate the funds competitively.

By then, since some of the disasters were three years old, the validity of the FEMA data for the traditional allocation was waning. While the Disaster Relief Appropriations Act required use of the best available data, the data were aging and losing credibility (HUD 2015). Furthermore, the formula used by HUD to determine unmet recovery needs relied on county-level data, and did not detect the most impacted and distressed areas at a more localized level. Since all but two states would be eligible to participate in a competition, HUD policymakers believed it was an appropriate way to elicit best available data to ensure appropriate distribution of the money to the most impacted and distressed areas. A competition is also efficient in that interested applicants would need to coordinate quickly and produce ideas together, which HUD staff hoped would lead to a positive outcome regardless of funding.

On September 17, 2014, HUD released a Notice of Funding Availability (NOFA) for the CDBG-DR National Disaster Resilience Competition (NDRC). The purpose of the NDRC was to help communities meet unmet disaster recovery needs and plan for long-term community resilience through a two-phase application process. The NDRC would encourage communities to think through the design and prioritization of programmatic and project-based actions to minimize long-term risks of future damage.

The following are goals of the NDRC:

- To apply science-based and forward-looking risk analysis to address recovery, resilience, and revitalization needs.
- **To leave a legacy of thoughtful, innovative, and resilient approaches to addressing future risks.**
- To help communities plan and implement projects that make them more resilient to economic stresses or other shocks.
- To fully engage stakeholders about the impacts of climate change and to develop pathways to resilience based on sound science.
- To leverage investments from the philanthropic community to help communities define problems, set goals, explore options, and craft solutions.

One of the NDRC goals is bolded to highlight HUD's intention to develop a product that outlasted a single funding application cycle. HUD expected the applications to have a lasting effect on communities and to create gold-star examples of comprehensive resilience interventions that could be implemented regardless of a federal funding award. The model of compiling a portfolio of resilience projects was designed to be replicated.

The competition also called for leverage – from philanthropy and from state and local agencies – so as to enable an expansion of the projects beyond NDRC geographies and activities (HUD 2015). HUD argued that since risks and extreme events do not have geographic boundaries, resilience should not either.

Eligibility

Eligible groups consisted of 67 cities, counties, and states with a Presidentially Declared Disaster in 2011, 2012, and 2013. The table below shows the types of incidents resulting from the 209 qualified disasters between January 2011 and December 2013. As many states and cities/counties were eligible based on multiple types of incidents, most applications focused on building resilience against one type of disaster. See Appendix 2 for more information on the qualifying disasters in each locality and state.

Table 1. Span of qualifying disasters for applicants. Source: Phase 2 NDRC Notice of Funding Availability.

	Incident Types
1.	Flood
2.	Severe Storm(s)
3.	Hurricane
4.	Severe Ice Storm
5.	Freezing
6.	Tsunami
7.	Fire
8.	Snow
9.	Earthquake
10.	Tornado
11.	Coastal Storm
12.	Mud/Landslide
13.	Other

In Phase 1, applicants framed their unmet disaster recovery needs, vulnerabilities, and community development objectives over a six-month period. They were invited to participate in workshops dubbed "Resilience Academies" run by the Rockefeller Foundation, which provided training, expertise, and tools to help communities understand resilience and risk in context, engage with communities, and develop strong applications (HUD Exchange n.d.).

Forty finalists were invited to participate in the four-month Phase 2, where applicants developed the design and BCA in an implementation plan of their proposal. These finalists ranged geographically, socio-economically, and by hazard. The grant minimum was set to $1 million and maximum to $500 million. Of the $1 billion, $181 million was dedicated for Hurricane Sandy recovery. HUD awarded funds to thirteen applicants: eight states and five cities or counties (Table 2).

Table 2. Funding awards of the thirteen CDBG-NDRC Finalists. Source: HUD 2015.

NDRC Winner	Award
States	
California	$70,359,459
Connecticut	$54,277,359
Iowa	$96,887,177
Louisiana	$92,629,249
New Jersey	$15,000,000
New York	$35,800,000
Tennessee	$44,502,374
Virginia	$120,549,000
Cities/Counties	
New York City	$176,000,000
New Orleans	$141,260,569
Minot, ND	$74,340,770
Shelby County, TN	$60,445,163
Springfield, MA	$17,056,880

2.2 National Disaster Resilience Competition (NDRC) benefit-cost analysis (BCA)

Origins of the NDRC BCA

Prior to the NDRC in 2015, no national funding agencies required consideration of qualitative co-benefits in standardized BCA methodology. Given the high limit on the funding proposals ($500 million), Ms. Kome was tasked with finding a way to ensure that the amount awarded was reasonable. Ms. Kome originated the idea to have an expanded BCA for the NDRC and explained the background and process for creating the framework at HUD during an interview.

Over the course of her 25 years at HUD, Ms. Kome had exposure to BCAs and read extensively about disaster recovery, mitigation, and resilience, including reports from the American Planning Association and initiatives by the Rockefeller Foundation for Rebuild by Design (Kome 2018). According to Ms. Kome, the framework for the competition emphasized iterating project designs and approaches to make each investment serve as many purposes as possible:

> "We wanted applicants to understand that resilience had more to it than just making a levee or a drainage project to protect against one bad day. Making applicants proposing large projects formally consider project benefits in resilience, social, economic, and environmental categories was **an expression of the thought that an investment of public funds should produce a wide range of daily/weekly/monthly/annual benefits and not just be about one bad day every thirty or forty years**." (Kome 2018).

As an example, Ms. Kome mentioned how a flood wall could be designed to include placemaking features such as steps or bleachers, which provides value to the public when the flood wall is not in use to serve its primary flood hazard risk mitigation purpose. Ms. Kome noted that the ideas were not necessarily new, but the concept of co-benefits had never previously been layered together in a BCA. Since the HUD Disaster Recovery program grew in 1992, the agency had been involved in several projects that accomplished multiple resilience and community objectives.

1997 Grand Forks Flood

In my interview with Ms. Kome, two projects in particular were mentioned as providing anecdotal proof of concept to the importance of co-benefits. The first is the case of Grand Forks, North Dakota and East Grand Forks, Minnesota. As its name suggests, Grand Forks is situated at the confluence of Red River of the North and Red Lake River. Since both rivers flow north, the town was susceptible to flooding when the flow met thawing Canadian snowpack. In winter of 1997, eight blizzards fed mountainous snowpack ("1997 Grand Forks Flood By The Numbers | FEMA.gov" n.d.). That April, 90 percent of the city was forced to evacuate (52,500 residents) when the flooding rivers breached the earthen levees designed to protect up to 52 feet; the Red River crested at 54.4 feet. The impact was severe: 83 percent (9,001) of Grand Forks homes, and 62 percent (751) commercial units were damaged. The downtown area caught fire; all 385 businesses were affected, and 11 historic buildings and 60 apartments burned. Water service was disrupted for weeks and 60,000 tons of flood debris was landfilled ("1997 Grand Forks Flood By The Numbers | FEMA.gov" n.d.).

The flood caused $4 billion in damages across the Red River Valley ("1997 Grand Forks Flood By The Numbers | FEMA.gov" n.d.). As a result of this catastrophic event, $409 million was appropriated for construction of a series of floodwalls, levees, flood pumping stations, storm sewers, diversion ditches, and recreational facilities in Grand Forks and East Grand Forks, with a federal contribution of $204.5 million ("20 Years Stronger - Flood Protection | City of Grand Forks, ND" n.d.). To build the levees, Grand Forks implemented a property buyout program that removed 800 homes from vulnerable areas. Across the river, East Grand Forks bought out 300 properties. These were the first large-scale property buyouts in the U.S.

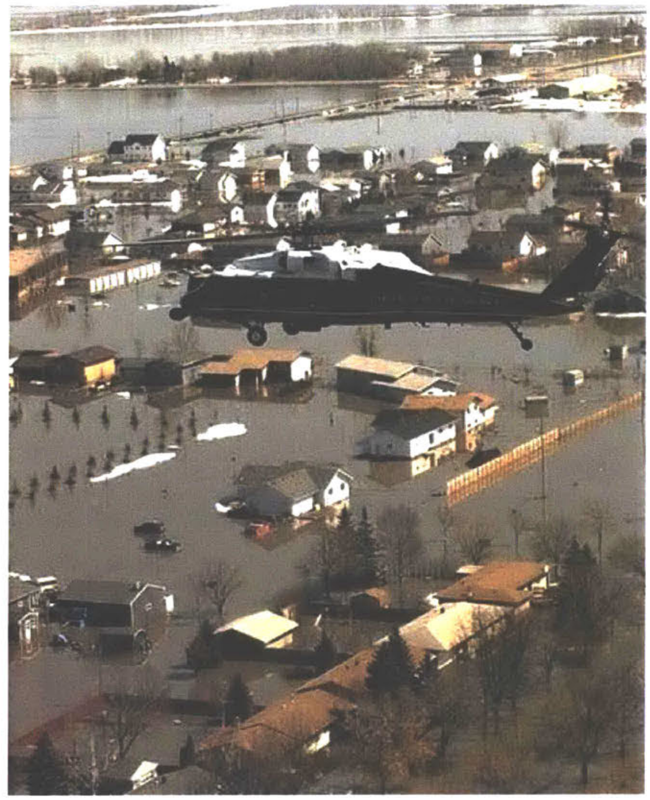

Figure 3. Damage of the 1997 Grand Forks flood, as seen from President Clinton's helicopter. The Presidentially Declared Disaster damaged 83 percent of homes and ignited the downtown area. Source: Stephen Jaffe (AFP/Getty Images).

The two communities collaborated across state lines to mitigate risk and increase resilience, supporting economic development in the process. Beyond downtown development in Grand Forks, which has become a "hub of nightlife, cultural, and community events" ("20 Years Stronger - Downtown Development | City of Grand Forks, ND" n.d.), the investment paved the way for a range of new opportunities. The buyout cleared space for a 2,200 acre greenway which, in addition to flood mitigation, continues to provide year-round recreation opportunities. A campground and cross-country ski area were established over former sites in the buyout area and the area grew famous for its spectacular skiing and wildlife fishing. In East Grand Forks, riverfront restaurants were elevated and now they draw visitors in to the network of small businesses, shops, and restaurants. When the next flood occurred, homes and the downtown area remained dry.

Hurricane Fran and the Neuse River Basin in North Carolina

Ms. Kome was directly involved with the recovery of Kinston and Goldsboro, North Carolina after Hurricane Fran struck the Neuse River in September 1996. The rainfall from the Category 3 hurricane brought the peak river flows to 12 feet and 9 feet above flood stage of the Falls dam in Goldsboro and Kinston, respectively (USGS 2013). The subsequent flood buyouts of 188 properties in 1997 were funded by a split contribution from FEMA's Hazard Mitigation Grant Program and HUD. Two years later, two hurricanes caused the Neuse River to overflow again. The flooding of over 1,000 homes and more than 300 businesses disproportionately affected low-income, African American residents (Institute for the Environment 2013), leading to HUD's close involvement in the recovery effort.

Over the course of eight years since the flood and the last HMGP grant, the City of Kinston purchased over a thousand homes in the floodplain, over 100 vacant lots, and several junkyards. According to Ms. Kome, the junkyards along the river had contaminated the soil with polychlorinated biphenyls. The recovery project removed this contamination, contributing to water quality improvements in the Neuse River which protect the health of downstream water users. The project also opened a recreational area and encouraged development in Kinston, NC.

Figure 4. The aftermath of Category 3 Hurricane Fran in North Carolina, September 1996. Source: Gary Allen of the News & Observer Publishing Co. in Raleigh.

In a recent review of a HUD funding allocation to the state of North Carolina, Kinston was no longer considered as one of the most impacted and distressed areas. "Now that's a resilience investment," said Ms. Kome. By the time the competition was proposed in 2013, Ms. Kome knew that co-benefits were a crucial piece of the resilience puzzle, and that BCA was a valuable tool to piecing it together. The next step was to adapt the tool to reflect the goals of the NDRC.

Process for developing the NDRC BCA

Modeled after Rebuild by Design and the traditional CDBG funding application, the NDRC application included sections on capacity, soundness of approach, need, leverage, and, if a project cost more than $50 million or spanned across county boundaries, a BCA. Through research on BCAs, Ms. Kome and her staff were surprised to find that that existing BCA practice focused exclusively on mitigation benefits, such as the number of lives in the case of a disaster—the one bad day every 30 years.

The HUD CDBG program allocates funding using a formula, and examines projects using metrics that reflect national objectives, such as the number of low- and middle-income jobs upon completion of the project, housing, and water and sewer service expansion. According to Ms. Kome, HUD inspects the CDBG proposals for what applicants will do to provide public services "today, not tomorrow, not later, but right away" (Kome 2018). As a result, the idea to include assessment of benefits in this BCA came naturally.

She assigned Meg Barclay to investigate how different federal agencies approach BCA, especially with regard to hard-to-quantify benefits. Ms. Barclay worked with the DOT, FEMA, OMB, and NOAA to learn the structure and justification for their BCAs. This assignment resulted in development of four benefit categories to include in the NDRC: Resiliency Value, Environmental Value, Community Development Value, and Economic Revitalization. The HUD team included the environmental category because many of the eligible areas included superfund sites or other environmental challenges that were either caused or exacerbated by the disaster as well as pre-existing. Their research uncovered that information about environmental degradation was often missed since agencies did not request it in the

BCA (Kome 2018). These three categories would supplement the traditional portion of the BCA dedicated to resilience. The result was a BCA similar to that which FEMA uses for its Hazard Mitigation Grant Program, with a more complete picture of a community's context.

The next step was to determine an appropriate way of grading the BCA. In a typical quantitative BCA, a benefit-cost ratio (BCR) is calculated and the project's BCR must exceed 1 to be deemed worthwhile. HUD planned to use more than the BCR to grade the proposal and, if reviewers were reasonably certain that the benefits outweighed costs, based on the combination of the qualitative and quantitative benefits, HUD would accept the submission.

Final NDRC BCA framework

In the final BCA framework, HUD emphasized co-benefits because "we want projects that are really, really great investments, not just good investments. We want them to be good for you every single day, not just on the one bad day you have every 25 or 50 or 100 years" (Kome 2018).

According to Ms. Kome (2018), one of the biggest achievements of the process was that HUD "unhook[ed] it from the purely quantitative and allow[ed] narrative." As adopted by a different BCA, HUD's framework prompted a level of certainty for qualitative benefits. While reviewers considered the BCR, they scored based on their certainty that the benefits were at least worth the costs, given the totality of evidence presented (quantitative and qualitative).

Ms. Barclay and other staff finalized a framework of "one of the simplest, most beautiful forms" (Kome 2018). The final framework bridged multiple levels of information and was called the BCA Narrative Table (see Table 3 below). Applicants who were admitted to Phase 2 of the NDRC and proposed an infrastructure project with an estimated total cost above $50 million or benefiting multiple counties were required to populate this template with line items of qualitative and quantitative co-benefits across the four benefit categories: Resiliency Value, Environmental Value, Community Development Value, and Economic Revitalization. HUD included this explanation in the BCA instructions submitted to applicants:

> "HUD recognizes that some benefits and costs may be difficult or impossible to quantify, and qualitative descriptions of benefits that cannot be monetized will be taken into account as evidence, as appropriate. Note that quantifying or otherwise accounting for social and ecological benefits and costs is a critical component" (HUD 2014).

HUD sent applicants a set of instructions on completion of the columns (discussed in detail in Section 4):

Table 3. Template for NDRC Narrative BCA Table. Source: HUD 2014

1	2	3	4	5	6
Costs and Benefits by category	Page # in Factor Narratives or BCA Attachment	Qualitative Description of Effect and Rationale for Including in BCA	Quantitative assessment (Explain basis and/or methodology for calculating Monetized Effect, including data sources, if applicable)	Monetized effect (if applicable)	Uncertainty
Life cycle costs					
				$	
Resiliency Value					
				$	
Environmental Value					
				$	
Community Development Value					
				$	
Economic Revitalization					
				$	

The result was a framework which encouraged applicant teams to learn how to design projects to have a greater community impact beyond disaster resilience. While the environmental and resilience benefits could be identified through research and using existing FEMA BCA methodology, the economic and social benefits required community input. The framework obligated teams to engage the community and incorporate what community members wanted into their proposals. Borrowing from the CDBG application, HUD required applicants to describe these consultations in the Phase 2 application and how they affected their overall proposal.

The competition was designed such that the BCA did not affect the factor scoring. The BCA results were factored in at the end, as HUD determined which portions of the highest scoring proposals to fund. It facilitated HUD's decision of resource allocation among projects within a winning proposal. The BCA attachment also includes the risks if the projects are not implemented as proposed, the estimated useful life of the projects, and the timeline for completion. All project cost estimates were estimated in 2015 dollars. In cases where operations and maintenance and/or lifecycle costs were included, the estimates were discounted to the present value using the OMB (A-94) discount rate of seven percent.

Section 3: Literature review

3.1 Climate change, disasters, and resilience

The power of broken economics: climate change and the BCA

Since the first Intergovernmental Panel for Climate Change (IPCC) report in 1990, the global response to the threat of climate change has been insufficient to reduce emissions by the amount necessary to maintain a stable atmospheric temperature. On a global scale, the urgency of climate change has grown relevant only since the publication of the Stern Review of the Economics of Climate Change in 2006 (Barker 2017). Barker et al. attributes this 26-year delay in part to the criticism by traditional economists of the information reported in the early IPCC publications. The first and second IPCC reports relied on a single-discipline BCA, which calculated costs much higher than benefits—to a prohibitive degree. Economists called for "delayed action until more information is available on the problem and more research and development has been done to lower the costs of any response" (Barker 2017).

The IPCC reports from 2001 onward shifted toward the use of a more comprehensive analyses (i.e., multi-disciplinary uncertainty analysis) which emphasized the urgency with which global decisions needed to be made to avoid the now-greater dangers of climate change (Barker 2017). The widespread acknowledgment of responsibility culminated most recently in commitments for mitigation and reforestation actions in the 2015 Paris Agreement developed by the United Nations Framework Convention on Climate Change.

Climate attribution science

Extreme weather events are "abrupt, occur in the present, and are highly visible," while the concept of long-term climate change trends seem "abstract, distant, and gradual" (Howe et al. 2014). Until recently, a skeptic could successfully dismiss climate change as the cause of extreme events – after all, a hurricane could be the result of an exceptionally strong La Niña season. While a flood might fall into the category of events predicted to rise with climate change, a particular area may have a history of flood. The distinction between weather and climate is "at the heart of the problem" (Allen 2003). Fifteen years ago, Dr. Allen wondered in his commentary "whether the attribution of specific weather events to external drivers of climate change will always be impossible in principle, or whether it is simply impossible at present, given our current state of understanding of the climate system." In 2004, Dr. Allen and his colleagues published the first extreme event attribution study, linking the 2003 heat wave across Europe to climate change, concluding that "it is very likely that human influence has at least doubled the risk of a heat wave exceeding this threshold magnitude" (Stott, Stone, and Allen 2004). According to the Earth Policy Institute, this heat wave was responsible for 35,000 deaths, mostly in France, Germany and Italy. This finding began the field of climate attribution science.

Since this publication, our ability to understand and explain extreme weather events in the context of climate change has grown rapidly. In 2016, the National Academies of Sciences, Engineering, and Medicine released a report evaluating the current state of the science, called the *Attribution of Extreme Weather Events in the Context of Climate Change.* Multiple expert committees compiled a substantial body of evidence showing that climate change has led to "discernible and quantifiable changes in the intensity and/or frequency of some types of extremes."

Since 2011, the Bulletin of the American Meteorological Society has released an annual report assessing the impact of climate change on the previous year's extreme events. In the 2016 edition (released in 2018), 21 of the 27 papers identified climate change as a significant driver of an extreme event. As the field of climate attribution science evolves, among other activities, researchers will be able to provide stakeholders with causal factors within days of an event and link future events to an integrated weather-to-climate forecasting effort (Committee on Extreme Weather Events and Climate Change Attribution et al. 2016).

In the coming years, advances in the models and remote sensing technologies have the potential to shift the conversation around a community's ability to predict the probability of extreme events and other local impacts of climate change. With more reliable forecasting of extreme events and a stronger connection between climate change and disaster, communities can build a stronger case through the use of the BCA to avoid disaster damages through pro-active implementation of resilience interventions.

What is resilience?

With weak national policy regarding climate change mitigation and adaptation as well as *ex-ante* disaster preparedness, U.S. cities and states are increasingly taking action at smaller scales to protect their communities from the impacts of climate change. For the NDRC, HUD defines a resilient community as one able "to resist and rapidly recover from disasters or other shocks with minimal outside assistance" (HUD 2015). This ability relies on curbing current and future risk in order to "maximize preparedness, save lives, and bring benefits to a community long after recovery projects are complete."

Resilience, defined in this context, seems to be a catch-all for vulnerability, risk reduction, disaster prevention, mitigation, response, and recovery. Indeed, the term resilience has adopted many definitions over the years, and its interpretation has evolved into a popular buzzword applicable to many phenomena and fields. Figure 6 shows the etymology of the term resilience across different disciplines over time. The range of interpretations and usages has led to confusion (Alexander 2013). Figure 6 orients the term within similar concepts in the modern sciences. Today, it is understood to be a multi-faceted concept positioned at the intersection of climate change adaptation, disaster risk

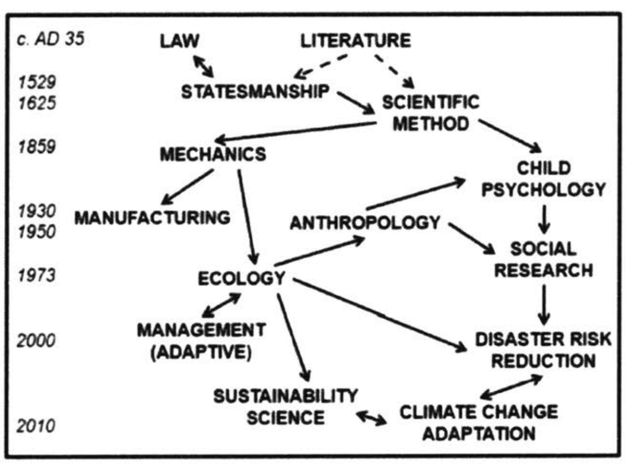

Figure 6. Schematic diagram of the evolution of the term resilience across disciplines over time. Source: Alexander, D.E. 2013.

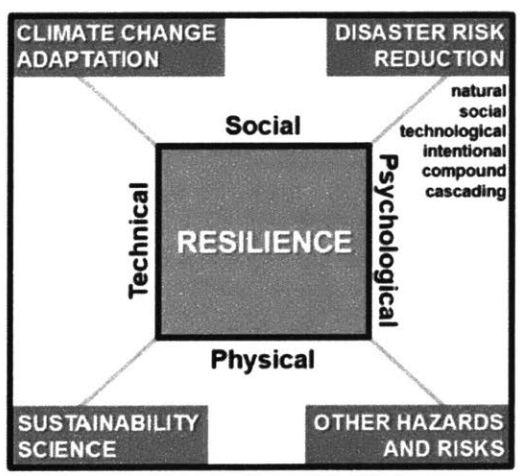

Figure 6. Summary of the position of resilience studies in the sciences. Source: Alexander, D.E. 2013.

reduction, and sustainability science, comprised of technical, social, psychological, and physical perspectives (Alexander 2013).

While HUD's explanation of resilience as representing an ability to bounce back has remained relevant over time and across fields, the definition provided for the purposes of the competition lacks specificity. This thesis uses a more refined definition of resilience, as developed by the United Nations Office for Disaster Risk Reduction (UNISDR) to disseminate international standard terminology related to disaster:

> "Resilience is the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions" (UNISDR 2009).

3.2 Co-benefits

Undervalued benefits and the *'Triple Dividend of Resilience'*

In 2015, the World Bank and the Global Facility for Disaster Reduction and Recovery published a report called *'The Triple Dividend of Resilience: Realising development goals through the multiple benefits of disaster risk management.'* Recognizing rising disaster losses, the need to strengthen *ex-ante* disaster risk management (DRM) investment, and limitations of existing appraisal methodology as identified in academic literature and policy frameworks, this report provides evidence of three types—or dividends—of benefits of DRM investment. The following year, the authors published a book which detailed this analytical method to enhance the business case for disaster risk management (DRM) investment. Acknowledging that the countries, cities, and communities pouring funding into resilience are those that have faced disaster, the authors identify the root causes of underinvestment in disaster resilience: a lack of resources, limited understanding of risks and impacts, and substantial political buy-in for post-disaster support.

A major constraining factor is that the benefits of resilience are hard for citizens to perceive, which leads to low political pressure for governments to change policy (Maskrey 1989). This creates a cycle where "less visible activities are more likely to be neglected, such as environmental protection," (Wilkinson 2012) since the costs present a visible and immediate burden while the benefits and their distribution are "unclear, uncertain, and distant" (Surminski and Tanner 2016). As a politician or policymaker, proposing resilience projects using the current appraisal system would be unwise given the absence of benefits and the pressing need for investment in other public sectors. For community members, a resilience or DRM project may seem like an exorbitantly costly effort to prepare for an event that has a low perceived probability of occurring, and whose nightmarish impacts seem hyperbolic, especially in areas that have yet to witness and feel the impacts of an extreme event. Benefits are undervalued in the current appraisal system.

The triple dividend of resilience, then, responds to this disconnect by shifting "away from a singular focus on losses as a driver for action and toward the recognition and appraisal of a broader set of dividends from investing in DRM" (Surminski and Tanner 2016). It builds a business case based on the wider benefits gained regardless of the occurrence of a disaster. The following three dividends comprise a way to elevate the externalities of a resilience investment in order to build a better business case that incorporates community wellbeing and even profit:

1. Avoiding losses when disasters strike;

2. Unlocking development potential by stimulating economic activity thanks to reduced disaster-related investment risks; and,
3. Social, environmental and economic co-benefits associated with investments.

The first dividend is typically met in current accounting methods and has a circular definition – surely a community invests in disaster risk management in order to better manage the risk of disaster. This is the basic rationale for DRM investment. The losses to which the dividend refers are human, physical, and financial. The human losses refer to the number of lives lost and people affected by a disaster. Given an effective resilience policy or intervention's primary goal is to save lives, an investment "pays off" when a disaster results in low mortality. For example, when an 8.2-magnitude earthquake and tsunami struck Chile in 2015, the investment in infrastructure upgrades as well as the existence and enforcement of building codes sheltered the community from a high death count (Surminski and Tanner 2016).

Direct damages usually refer to physical damages to property, infrastructure, and other assets through investment in infrastructure, early warning systems, and planning. Other direct damages refer to the impact that ripples through a community after the disaster. The ripple effects from a business perspective, for example, include the impacts of the disaster on a product's supply chain, both upstream to materials sourcing and downstream to the client base.

The World Bank created a classification to reflect this range of vulnerability (Tanner et al. 2016):

- Structural: retrofitting and reinforcement of public buildings, such as schools, hospitals, fire stations and administrative buildings
- Non-structural: the resettlement of vulnerable populations in high-risk areas
- Functional: protection of people and assets, so they remain functional during and immediately after an emergency.

The latter two dividends are overlooked in appraisals and investment decisions and represent services and perks to communities every day, regardless of whether or not the rare disaster occurs. See Figure 7 for a summary of the logic and structure of the *Triple Dividend of Resilience*. As shown in Figure 7, unlocking the economic potential and generating co-benefits provide value regardless of disaster. By incorporating co-benefits into the calculation, a range of positive externalities and multi-functional interventions are revealed.

The second dividend of resilience, dubbed "unlocking economic potential," promotes *ex-ante* investment in DRM, encouraging the private sector to invest in risk-taking. According to the *Triple*

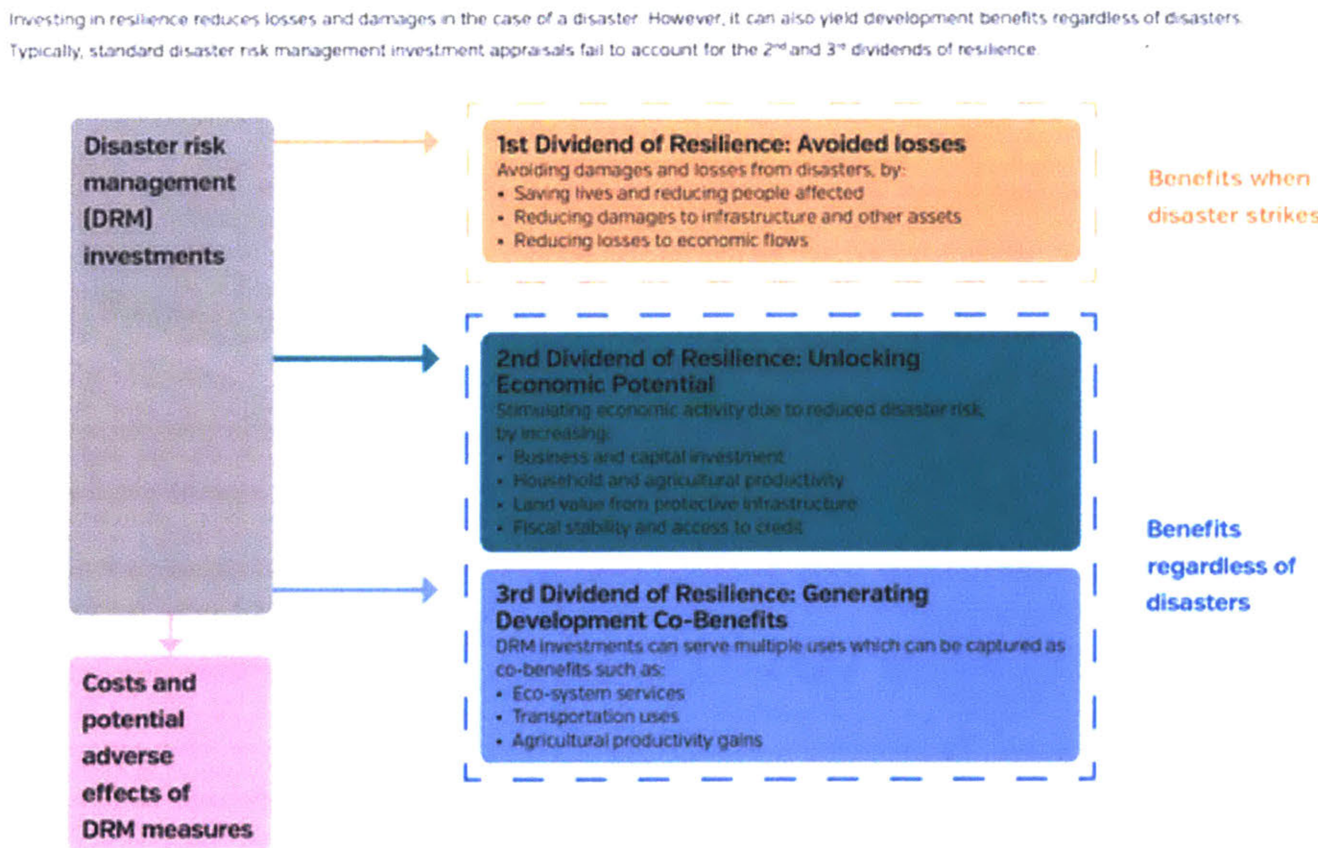

Figure 7. The Triple Dividend of Resilience—strengthening the case for investing in DRM. Source: Tanner et al, 2016.

Dividend of Resilience, this dividend includes four types of benefits:

- Economic gains from positive risk-taking, such as entrepreneurship and innovation;
- Investments in productive assets, such as in small-scale agriculture;
- Extending planning horizons, such as for building up savings; and,
- Increase in land values after DRM investment, in which investment in infrastructure protecting properties from disaster, such as dams and levees, increase the value of the land.

This thesis focuses on the third dividend of resilience: co-benefits of specific investments that manage risk. These co-benefits materialize independent of a disaster, and provide economic, social, and environmental value to a community. Through intentional design of "multi-use" projects, both resilience and community development objectives can be achieved – in tandem. This is especially useful for costly infrastructure projects, whose resilience benefits alone may not justify the necessary upfront capital. In the context of the limited budgets in U.S. cities and states, a resilience project is more attractive when it also serves the purpose of creating jobs, realizing ecosystem services, and improving access to education and social services.

The idea of co-benefits is not new; however, existing literature focuses on climate change policy (Fung and Helgeson 2017). Among the work produced by the World Bank and the Rockefeller Foundation, and by Rodin's work (2014) in coining the resilience dividend, a common theme in the literature is the need for a standard assessment methodology (Fung and Helgeson 2017).

A methodology does not resolve the larger problem of determining what constitutes a co-benefit. Furthermore, "the proportion of papers dedicated to the quantification of co-benefits is relatively small" (Fung and Helgeson 2017). Since the competition organized co-benefits into three categories, the following sub-sections introduce co-benefits organized by relation to community development, environment, and economic revitalization.

Community development co-benefits & valuation

Several initiatives seek to elevate awareness around and facilitate measurement of the social impacts of investment. The UN Environment Programme Finance Initiative and the UN Global Compact popularized an expectation that both public and private investment decisions consider a broader contribution to sustainable development (Vorhies and Wilkinson 2016). The UN promotes incorporation of environmental, social and corporate governance (ESG) issues into investment analysis and decision-making processes and UN climate meetings reaffirm global political commitment to integrating DRM into public and private investments and planning for growth and development:

> We stress the importance of stronger interlinkages among disaster risk reduction, recovery and long-term development planning, and call for more coordinated and comprehensive strategies that integrate disaster risk reduction and climate change adaptation considerations into public and private investment, decision-making and the planning of humanitarian and development actions, in order to reduce risk, increase resilience and provide a smoother transition between relief, recovery and development.

Impact investing brings ESG to the forefront of many organizations as the private sector aligns investments with the U.N. Sustainable Development Goals. These investments are intended to generate a measurable, beneficial impact to societies in addition to a financial return. While ESG is not related specifically to resilience, the framework for ESG metrics is helpful in thinking about measurement of social impacts of an intervention. The framework categorizes the Sustainable Development Goals into five "actionable impact themes:" basic needs, empowerment, climate change, natural capital, and governance ("ESG Sustainable Impact Metrics - MSCI" n.d.). These themes address the 17 Sustainable Development Goals through social impact metrics of nutrition, major disease treatment, sanitation, affordable real estate, finance, and education. However, this structure is designed to measure revenue data.

Quantification of social progress as a result of resilience intervention remains at an early stage. The Social Vulnerability Index for the United States (SoVI) measures the social vulnerability of U.S. counties to environmental hazards. First developed by the Centers for Disease Control's Agency for Toxic Substances & Disease Registry in 2006, the SoVI index is a comparative metric, or tool, which helps emergency response planners identify and map communities that need support before, during, and after a hazardous event by analyzing 14 social factors using American Community Survey data ("ATSDR - The Social Vulnerability Index - Home Page" n.d.). While these factors only indicate vulnerability and do not propose a causal relationship with resilience, they can be used to track progress over time. The factors in bold represent potential indicators for co-benefits which can be monitored by using American Community Survey data and which are supported by other literature: **Socioeconomic status**, gender, race and ethnicity, age, **residential property**, **renters**, **occupation**, **family structure**, **medical services and access**, **education**, social dependence, special-needs population, and **employment loss**.

Health is a common denominator across these indices. The World Health Organization Health Economic Assessment Tool (WHO HEAT) developed a methodology and guidance to quantify the health effects of transportation infrastructure and policies in relation to walking and cycling for use in BCAs (Kahlmeier et al. 2017). This tool was informed by systematic literature review of cycling and walking project economic analyses in the U.K., and draws the economic relationship between physical activity and health and air pollution and health. The guidance describes urban planning which promotes cycling and walking as a "win-win approach: it not only promotes health but can also lead to positive environmental effects, especially if cycling and walking replace short car trips" (Kahlmeier et al. 2017).

Related directly to resilience, several case studies from outside the United States identify the following social co-benefits: tourism (Larsen, Calgaro, and Thomalla 2011), recreation (Tomczyk, White, and Ewertowski 2016), and increased community awareness and preparedness (Khew et al. 2015). Rodin (2014) presents case studies that show the potential for resilience to improve social services and create more broadly shared prosperity.

Environmental co-benefits & valuation

Environmental co-benefits of resilience are gained from the implementation of projects which expand open spaces and wetlands, provide connectivity between neighborhoods and waterfronts, and offer public gathering spaces. For example, flood peak reduction actions designed with nature in mind are likely to have co-benefits for not only coastal resilience, but also for quality of life by improving urban living conditions (Larson and Perrings, 2013). An intervention's improvement of environmental qualities may increase property values (Mitchell Polinsky and Rubinfeld, 2013); however, such actions can adversely affect social justice and social cohesion by contributing to gentrification (Haase et al., 2017).

Much attention has been given to environmental co-benefits, typically in terms of interpreting nature's values as ecosystem services – i.e., services that the natural world contributes to human wellbeing. Through this utilitarian perspective, environmental co-benefits have been more widely identified and quantified than other co-benefit types. There are several reputable sources which assess the economic value of these services.

Based on review of 1700 science and practice documents, members of the E.U.'s EKLIPSE Expert Working Group on Nature-Based Solutions to Promote Climate Resilience have developed a framework to assess co-benefits and costs to what they dub "nature-based solutions" (NBS) in lieu of ecosystem services (Raymond and Centre for Ecology and Hydrology (Great Britain) 2017). This approach merges established ecosystem-based approaches, such as *ecosystem services*, *green-blue infrastructure*, *ecological engineering*, *ecosystem-based management* and *natural capital* with assessments of the social and economic benefits of resource-efficient and systemic solutions. Combining technical, business, finance, governance, regulatory and social innovation concepts, ten challenges were identified: 1) Climate mitigation and adaptation; 2) Water management; 3) Coastal resilience; 4) Green space management (including enhancing/conserving urban biodiversity); 5) Air/ambient quality; 6) Urban regeneration; 7) Participatory planning and governance; 8) Social justice and social cohesion; 9) Public health and well-being; and 10) Potential for new economic opportunities and green jobs.

The idea is that NBS that seek to address these challenges would support climate resilience, at least in urban areas. Authors note "strongly encourage researchers and practitioners to move from the assessment and valuation of ecosystem services to a wider assessment of the co-benefits (and costs) of NBS through the lens of co-production of ecosystem services" (Raymond and Centre for Ecology and Hydrology (Great Britain) 2017).

In the U.S., the major sources for environmental co-benefit valuation are the USDA, FEMA, and Earth Economics. The FEMA Environmental Benefits Calculator for Acquisition Projects bases its assessment of services such as water quality improvement and pollination based on land type and lot size. FEMA Mitigation Policy FP-108-024-01; Starting in June 18, 2013, FEMA released the policy titled Consideration of Environmental Benefits in the Evaluation of Acquisition Projects under the Hazard Mitigation Assistance (HMA) Programs, which sought to incorporate environmental benefits into the BCA used to demonstrate cost effectiveness for acquisition projects funded by FEMA. The purpose of this policy is to identify and quantify the types of environmental benefits that FEMA will consider in the BCA for acquisition projects, applicable to the FEMA HGMP for major disasters. As the project-based tool translates well to the competition, this tool is discussed in detail in the Methods section of this thesis.

Earth Economics summarizes various methodologies for valuation of ecosystem services in Table 4. This table is helpful in thinking of ways to determine the economic value of benefits that do not have market prices, such as through willingness to pay or stated preferences.

Table 4. Primary Valuation Methodologies for Ecosystem Goods and Services. Source: Earth Economics, Louisiana Phase 2 NDRC application.

Method	Description
Market Value (M)	The value that an ecosystem good is sold for in a market.
Avoided Cost (AC)	The value of costs avoided that would have been incurred in the absence of particular ecosystem services. Example: The hurricane protection that is provided by barrier islands avoids property damages along coastlines.
Replacement Cost (RC)	The cost of replacing ecosystem services with man-made systems. Example: Natural water filtration is replaced with a costly man-made filtration plant.
Factor Income (FI)	The enhancement of income by ecosystem service provision. Example: Water quality improvements increase commercial fisheries catch and thereby also the incomes of fishermen.
Travel Cost (TC)	The cost of travel required to consume or enjoy ecosystem services. Travel costs can reflect the implied value of the service. Example: Recreational areas attract tourists. The value they place on that area must, at a minimum, be at least the price they were willing to pay to travel to it.
Hedonic Pricing (HP)	The reflection of service demand in the varying prices people will pay for associated goods. Example: Housing prices of properties in close proximity to recreational areas can be higher than those that are farther from these areas.
Contingent Valuation (CV)	The value for service demand elicited by posing hypothetical scenarios that involve some valuation of land use alternatives. Example: People would be willing to pay for increased wetland restoration, as expressed through surveys.
Group Valuation (GV)	Discourse-based contingent valuation, which is conducted by bringing together a group of stakeholders to discuss values in order to determine

Method	Description
	society's willingness to pay. Example: Government, citizen groups, and businesses come together to determine the value of an area and the services it provides.

Earth Economics' Ecosystem Valuation Toolkit contains a repository of published, peer-reviewed primary valuation studies; however, public access to the database is not available. Methods for assessing value of services are not aligned with governmental approaches. For example, to continue with the health example, exercise has a major influence on an individual's health. Accessible outdoor recreation can increase the exercise rate of a surrounding population by as much as 48%. Improved health due to increased exercise leads to reduced health care costs and increased work productivity. Earth Economics uses participation rates based on statewide recreation activity, collected through an Outdoors Demand Survey, to estimate benefits in the Target Area. FEMA generalizes the benefit through a per-acre monetary estimate.

It is important to note that while ecosystem services are produced by the natural environment, they can provide social, environmental, and economic co-benefits.

Economic co-benefits & valuation

Disaster strongly impacts the economy through disruption and displacement of businesses and homeowners. However, while resilience may prevent financial losses to industry, these avoided costs are not co-benefits in the sense that they do not occur in the absence of disaster. Economic gains should instead be based on the potential addition of new retail and commercial space, job growth, and increased participation in the economy. However, there is only "anecdotal evidence of improvements to community budgets, economic diversification, and greater social and economic opportunities for residents from community resilience planning" (Fung and Helgeson 2017).

3.3 BCA as a resilience tool

BCA fundamentals

The BCA aids the identification of the best of a determined number of options to maximize human benefits and minimize costs. A traditional BCA measures costs and values in financial terms and produces a net present value (NPV) or a benefit-cost ratio (BCR) which is a quick indicator of the expected value of a project relative to its cost. In general, the higher the BCR and the NPV for the useful life of the proposal, the higher the economic payoff of the covered project. *Ex-ante* analysis is most useful for identifying whether resources should be allocated to a project under consideration. It addresses the challenge of uncertainty about a project's impacts and the net benefits. As more becomes known about the project's impacts as it progresses, other types of BCA (i.e., *ex-post* and *in medias res*) can be conducted.

The BCA appeals to a broad audience, and is especially useful to communicate with those in the arena of public investment economics, since the result is simple to interpret and easy to include in other financial calculations of a policy or project. The process of assigning a value to health and the environment is complex and relies on a multitude of assumptions. Sagoff notes that the steps and tasks to complete a BCA, from initial identification of factors through comparing summaries across alternative scenarios are "Herculean,"(Sagoff 2008).

The main principles and features of a traditional BCA are shown in the table below.

Table 5. Main principles and Features of a BCA. Source: Satya-Lekh et al 2014.

	Principles	Features
1	With and without approach	CBA compares the situation with and without the project/investment, not the situation before and after.
2	Focus on selection of the "best option	CBA is used to single out the best option rather than calculating the desirability of undertaking a project per se
3	Societal point of view	CBA takes a societal welfare approach. The benefits to society have to outweigh the costs in order to make a project desirable.
4	Revealed versus expressed preferences	In the revealed preference approach, market prices for the goods under scrutiny (such as the value of material used for reconstructing a building after a disaster) can be observed and used. Those values often cannot directly be observed, however (e.g, a general value for "protection" against natural disasters), and the expressed preference approach is used, where preferences are gathered through surveys
5	Clear definition of the boundaries for the analysis	Count only losses within the geographical boundaries in the specified community/area/region/ country defined. Impacts or offsets outside these geographical boundaries should not be considered

The BCA is an imprecise science; factors that affect health and other social factors are often indirect and cannot be attributed to a specific project. Furthermore, BCA also have a geographic boundary and do not account for transboundary costs and benefits.

BCAs in practice

The basic social BCA model builds on standard commercial, financial cost–benefit analysis and was originally developed in the late 1960s in response to demands on the government to build basic infrastructure (Cameron and World Health Organization 2011). The technique gave power to economists to compare development activities against an international standard in terms of their net benefits to the global human condition. The social BCA claimed to capture market failures, including absent markets (e.g., for environmental goods); externalities (e.g., air and water pollution); public goods; imperfect competition (e.g., private ownership of a natural resource); and government regulations (e.g., subsidies on agricultural products affecting water quality), (Cameron and World Health Organization 2011).

BCA and resilience theory and practice are "potentially and demonstrably beneficial in addressing so-called 'wicked' problems such as climate change," (Knight-Lenihan 2016) and can be used to measure social welfare. Some reported challenges of applying the BCA to climate change are its long timeline and the inequitable distribution of action relative to where the greatest impacts are likely to occur (Knight-Lenihan 2016). However, given recent advancements of attribution science, the BCA can relate to climate change in the context of disaster resilience.

The Federal Emergency Management Agency (FEMA) maintains a BCA tool for use in conducting benefit-cost analyses for applications submitted under FEMA's Hazard Mitigation Assistance (HMA) Grant Programs. The tool contains methods for estimating benefits of the most common resilience benefit categories for buildings (e.g., building damage, displacement, and loss of function), utilities (e.g., electricity, water supply, and waste water treatment), and services (e.g., fire services, police services).

The FEMA BCA tool comprises several modules to estimate expected damages from natural disasters, such as floods, hurricanes, tornados, and earthquakes.

3.4 Literature Gaps

The literature highlights "a need for an analytical framework for comparing resilience policies that includes co-benefits for the community at large" (Fung and Helgeson 2017). Specifically, Hung and Helgeson (2017) note that "the question remains—how should decision makers incorporate the potential co-benefits of an investment into their evaluations? At the heart of this question is the fundamental problem of quantifying co-benefits."

Studies demonstrate that co-benefit evaluation is an important tool to build support of stakeholders for resilience projects. While studies show the connection between co-benefits and BCA as well as between evidence-based analyses like BCA and stakeholder support, literature exposes a need for more case studies and real-world examples of how communities are thinking about co-benefits, specifically in the context of resilience. Little information has been published on resilience co-benefits in the U.S., in contrast to climate change co-benefits or studies on disaster interventions from the perspective of international aid organizations. Furthermore, the literature dedicated to the quantification of co-benefits is relatively sparse (Fung and Helgeson 2017).

Section 4: Methods

This section discusses the methodology to analyze the NDRC BCAs as well as the process for interviews with competition winners and unfunded finalists to provide context to the BCA application process and outcomes.

4.1 BCA crosswalk

The BCA crosswalk refers to the table I created to summarize the results from the NDRC BCAs for this thesis. This crosswalk maps the identification and quantification of co-benefits by the applicants by compiling and coding reported benefits from the Narrative BCA tables.

Data collection

My first step was to collect the BCA attachment from as many of the forty Phase 2 applications as possible. While the applications are public documents, approximately half were accessible online, either published on the applicant's NDRC web page or in government archives. I requested the remaining files either by email to the point person of the application (if the contact information was available in Phase 1 application materials or Phase 2 public drafts) or through government document request systems, when no other information was available. In total, I collected 32 Narrative BCA Tables out of 40 (80%). Of these, 28 applications included at least one project which triggered the BCA requirement and followed the proper tabular convention.

Coding process

In the BCA crosswalk, I developed codes—short phrases—to consolidate and represent the various types of benefits reported by applicants. While HUD did allow a supplemental narrative of three pages in the body of the application to provide support for qualitative co-benefits (HUD 2014), this thesis examines only the benefits explicitly recorded in the Narrative BCA Table. If applicants explained benefits elsewhere, they were not coded in this analysis but may be discussed for context. I also extracted the use of consultants as well as the BCR from the BCA attachment, as available.

If the benefit reported was a general category that was not further disaggregated in the 'Quantitative Assessment' or 'Qualitative Description' column (e.g., *ecosystem services*), even if the applicant intended to apply the benefit to multiple categories, I did not conduct further investigation in the body of the application due to the volume and length of applications. This universe of data is not perfect, but comprises the reality of responses to HUD's prompt to be creative. The format of the tables ranged from a two-page PDF with nearly illegible text to a publicly accessible Excel workbook displaying calculation formulas. This underlines the point that some benefits were not thought of as important or tangible enough to include in a BCA.

Aggregation

Applicants reported similar benefits in a non-standardized way, necessitating interpretation to synthesize and code the information. For example, a project with a transportation element, such as construction of a new highway, may report benefits in a number of ways. Below is a sample list of the ways in which traffic reduction was reported across the applications as a benefit in the Community Development Value category:

- Annual Savings in Vehicle Operating Costs
- Avoided Traffic
- Annual Gallons of Motor Vehicle Fuel Saved
- Annual Hours of Motor Vehicle Delay Saved
- Annual Cost of Motor Vehicle Congestion Saved
- Shorter Commuting Distances for the Traveling Public
- Reduced Travel Time for the Traveling Public
- Reduced Vehicle Use

Some applicants disaggregated traffic benefits in a way that allowed quantification of multiple factors related to traffic. For example, the City of Minot, ND reported *'annual gallons of motor vehicle fuel saved'* to represent financial savings for the driver by stretching the gas tank for a longer duration of time, and reported *'annual hours of motor vehicle delay'* to represent the time value and the opportunity cost of the driver. Another applicant may simplify the benefits to a general claim of *'avoided traffic.'* All of these benefits were coded in the BCA crosswalk as one benefit type, *'Avoided Traffic and Reduced Vehicle Use',* to capture time and gas savings generally.

A similar example exists in the Community Development Value category. While the State of California's BCA discussed health with respect to the reduction in wildfires mitigating human exposure to smoke, Minot, ND reported health benefits in the context of a new farmer's market opening along a proposed greenway project at a downtown gathering place. In the County of Shelby, TN, health benefits were identified and quantified in three ways: *'Healthcare Benefits Annually'*, *'Average Annual Medical Costs'*, and *'Asthma and Cancer Rates'*. In other BCAs, *'exposure to illness'* due to evidence of higher illness rates in emergency shelters was the health benefit. Despite the variation in why the intervention protected human health, these benefits achieved a similar purpose thus were coded under *'Reduced Medical Costs / Improved Health'*.

Disaggregation

In some cases, a reported benefit overlapped two codes. For example, in West Virginia, a waterline extension project is projected to provide potable water to 1,750 people, obviating reliance on private wells:

> "Water-related diseases and contaminants found in private wells include the following: arsenic, copper, *Cryptosporidium*, *Campylobacter*, *E. coli*, Enterovirus, *Giardia*, Hepatitis A, lead, nitrate, Norovirus, radon, Rotavirus, *Salmonella*, and *Shigella*. Most existing wells in the Target Area do not currently meet safe drinking water standards due contamination from previous mining activities" (West Virginia 2015).

I coded this as a social benefit under *'improved health'* (i.e., reduced human exposure to known contaminants) as well as an environmental benefit of *'violations/compliance'*, whereby the drinking water served to the public will meet the standards under the Environmental Protection Agency's Safe Drinking Water Act.

Property values

In the instructions, HUD identified two types of impacts on property value: those due to direct risk reduction and those due to other benefits independent of disaster risk, such as downtown economic revitalization or proximity to a greenway. To maintain this distinction from the instructions, this thesis contains two codes for property value: one under the resilience category and one under community development category.

For example, Cook County, IL separated the property value estimates as instructed, indicating that 1) property values along the roads included in the green streets program will increase by 3.5 to 5 percent when trees, vegetation, and green infrastructure are installed, affecting 918 homes and 2) property values are expected to rise by 2 to 8 percent when homes are no longer subject to flooding in the project area (Cook County 2015). However, most applicants included property values as a single line item benefit, without making the distinction between resiliency and economic revitalization. The explanation of the impetus for the value increase was often described in the BCA Narrative Table, and coded accordingly.

BCA instructions for applicants

One important factor is that applicant BCAs may have replicated the benefits offered as suggestions in the instructions. In the BCA instructions for applicants, HUD created the following definitions and examples for the four categories of benefits with some ambiguous or unclear definitions, as shown in Table 6. Instructions that posed problems in the coding process are in **bold** text.

Table 6. BCA instructions for NDRC Phase 2 applicants by HUD. Source: HUD 2014.

Resiliency value includes value of protection from the effects of future/repeat disasters, including, but not limited to, flood, wind, fire, earthquakes, such as:

- **Reduction of expected property damages due to future/repeat disasters**
- Reduction of **expected casualties** from future/repeat disasters
- Value of reduced displacement caused by future/repeat disasters
- Reduced vulnerability of energy and water infrastructure to large-scale outages

Environmental Value factors may fall into the following categories

- Ecosystem and bio diversity effects (e.g. from wetlands restoration or reforestation)
- Reduced energy use
- Noise levels
- Climate change – Reduced Greenhouse Gas emissions
- Air Quality – Reduced criteria pollutants (nitrogen dioxide (NO2), ozone (03), sulfur dioxide (SO2) and particulate matter of aerodynamic diameter of the micrometers or fewer (PM-10)
- Water quality – reduced stormwater runoff
- Reduced urban heat-island effect

Social value includes benefits that would further Community Development objectives may fall into the following categories:

- **Reductions in human suffering (lives lost**, illness from exposure to environmental contamination, asthma and cancer rates in low income and minority populations living in areas with greater environmental risk)
- **Benefit to low- and moderate-income persons and/or households**
- **Improved living environment** (such as elimination of slum and blight conditions, improved community identity and social cohesion, improve recreational value, greater access to Cultural, historic, archaeological sites and landscapes, equal access to resilient community assets)
- Greater housing affordability

Economic Revitalization benefits may fall into the following categories:

- Direct effects on local or regional economy (e.g. tourism revenue) net of opportunity costs.
- **Value of property other than through enhanced flood protection, independent of increases in property value captured by other benefits in the BCA or that might otherwise have occurred without the proposed project.**

The instructions embedded redundancy and confusion into the BCA process, as these suggestions are not based on existing standards and do not adhere to terminology already in use by most applicants. Notable conflicts and points of inconsistency are as follows:

- Property values are expected to be taken into account in two categories: Resiliency and Economic Revitalization.
- Casualties are expected to be taken into account in two categories: Resiliency and Community Development.
- The co-benefits listed under the Environmental Values category are similar to but not the same as the metrics and estimates commonly used to evaluate ecosystem service benefits under FEMA's Hazard Mitigation Grant Program. This is described in further detail later in this section.

The phrases suggested by HUD to express social co-benefits are vague and potentially misleading to applicants. *'Improved living environment'*, for example, is not a single benefit; it can apply to nearly any aspect of daily life. As a result, applicants referred to a range of topics and metrics under this umbrella.

Similarly, *Benefit to low- and moderate-income (LMI) persons and/or households* is not a single co-benefit. Since HUD's interest in the disaster space focuses on most distressed areas and vulnerable populations, this category is built in to the design of the competition. All proposals are designed to predominantly benefit LMI communities, based on the geography, programming, development opportunities, and workforce training. The instructions do not encourage applicants to list specific benefits. My approach to coding these benefits is discussed throughout this section.

Since the list of benefits was first based on BCA Narrative Table entries as opposed to the instructions, I captured the most popular terminology used to describe the benefits embedded within this phrase, and separately coded recurring topics that warrant distinct consideration. The first is *community identity and social cohesion*, which was mentioned in half of the BCA Narrative Tables (14 out of 28). The second was *historic and cultural amenity preservation*. I retained the language suggested in the HUD instructions, converting to living conditions *and environment* given the language and topics reported in the applications. Below are examples assigned to this code:

- Missouri: Elimination of properties in subpar condition through rehab loan program; reduced blight; quality of life.
- Texas: Significant positive effects in preserving the quality of the environment (aesthetic elements; fire damage to trees and other aspects of the natural landscape).
- Tennessee: Slums will be reduced, local tax revenue will increase, and education will improve, resulting in a better standard of living.

The other example identified previously in this section was *Benefit to low- and moderate-income persons and/or households*. I kept this language as a benefit code where applicants used it without providing further detail, and assigned a more specific code where possible (e.g., if the benefit in fact revolved around providing greater access to schools). For example, Colorado described the benefit *enhanced economic opportunities for low-income communities* using only circular rationale: "Project implementation and induced development would increase economic opportunities for Low Income Communities," (Colorado 2015). It is unclear what specifically would provide these opportunities that is not already covered elsewhere.

For example, Cook County, IL separated the property value estimates as instructed, indicating that 1) property values along the roads included in the green streets program will increase by 3.5 to 5 percent when trees, vegetation, and green infrastructure are installed, affecting 918 homes and 2) property values are expected to rise by 2 to 8 percent when homes are no longer subject to flooding in the project area (Cook County 2015). However, most applicants included property values as a single line item benefit, without making the distinction between resiliency and economic revitalization. The explanation of the impetus for the value increase was often described in the BCA Narrative Table, and coded accordingly.

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Environmental Benefits in the Evaluation of Acquisition Projects under the Hazard Mitigation Assistance Programs), the BCA crosswalk reverts to FEMA language where applicable.

As shown in Figure 8, FEMA proposes two classifications of environmental co-benefits. Since the applicants had discretion to identify benefits within the Environmental Value category, the NDRC BCAs included two styles of co-benefit identification: 1) a sum total estimated value for green open space and riparian land, respectively, and 2) estimates by specific ecosystem service (e.g., erosion control). In the BCA crosswalk, I kept the green open space and riparian categories as separate codes, to account for instances where applicants used the sum total of ecosystem services for that land type. I also recorded specific ecosystem services when they were disaggregated or when other sources were used.

Environmental Benefit	Green Open Space	Riparian
Aesthetic Value	$1,623	$582
Air Quality	$204	$215
Biological Control	--	$164
Climate Regulation	$13	$204
Erosion Control	$65	$11,447
Flood Hazard Reduction	--	$4,007
Food Provisioning	--	$609
Habitat	--	$835
Pollination	$290	--
Recreation/Tourism	$5,365	$15,178
Storm Water Retention	$293	--
Water Filtration	--	$4,252
Total Estimated Benefits	$7,853	$37,493

Figure 8. Annual Estimated Monetary Environmental Benefits per Acre per Year. Source: FEMA Mitigation Policy FP-108-024-01.

Note that *'Flood Hazard Reduction'* is an environmental benefit under this list. *'Hazard reduction'* is also included under the Resiliency category to capture other incident types beyond flooding and in cases independent of ecosystem services. Similarly, *'Recreation/Tourism'* is included as an environmental benefit and was coded as such with direct relation to natural landscapes, such as for increased birdwatching and fishing opportunities. *'Recreational value'* and *'tourism/economic impact'* are separated as community development co-benefits with reference to amenities such as a new bicycle path and downtown revitalization.

Benefit quantification

The BCA crosswalk also records whether the applicant chose to provide a quantitative calculation of the co-benefit or, if no quantitative information was available, a qualitative description. Purely for analysis purposes, the BCA crosswalk records "1" when a monetary value was assigned to a co-benefit and "0" for projects with only qualitative descriptions. A "0" was assigned to any responses in the following qualitative classifications provided in the BCA instructions:

--	Expected strong negative impact
-	Expected negative impact
0	Neutral
+	Expected positive impact
++	Expected strong positive impact
?	Impact unknown / cannot be assessed

In cases where applicants reported the same co-benefit qualitatively and quantitatively, the BCA crosswalk assigned "0/1."

Analysis

This thesis displays the results of the BCA crosswalk through graphs and charts developed in Microsoft Excel. Results are shown and discussed further in Section 5.

- Stacked bar charts are used to show the frequency of resilience co-benefits as well as their quantification by totaling the number of NDRC BCAs (out of 28) which reported a co-benefit coded within a category and the percentage of those which included a monetary value (i.e., included a "1" code for quantification).
- A sunburst diagram shows the frequency and quantification level of the three co-benefit categories.
- A clustered bar chart is used to compare BCRs and co-benefits by NDRC applicant.
- Tree maps show the hierarchy of perceived co-benefits in each of the four U.S. Census regions: Northeast, Midwest, South, and West.

4.2 Interviews

Through semi-structured interviews, I sought to draw out the contextual information that explains the applicant team's approach for developing their applications and BCA, from brainstorming potential impacts with consultants to estimating and interpreting quantitative data or narrative descriptions of co-benefits. See Appendix 4 for a sample interview guide.

I conducted six interviews, five of which with Phase 2 finalists, including three competition winners and two unfunded finalists. I spoke with public servants who took leadership roles for the NDRC from a mix of local government applicants and state applicants, geographies across the U.S., urban and rural areas, and incident types. In the Western U.S., I spoke with Sue Naramore, who led California's winning wildfire proposal, and Yumei Wang, a project manager for the Oregon's unfunded application which focused on rural resilience to earthquake and tsunami. Inland, I spoke with Jessica Turba, the project team lead for Iowa's winning watershed proposal to minimize flood risk, as well as Iain Hyde, then-Deputy Director of the Resiliency and Recovery Office for Colorado, an unfunded finalist. In the northeast, I spoke with Tina Quagliato, who led the winning application for the City of Springfield, MA.

4.3 Limitations

The BCA crosswalk lacks data from 12 of the 40 NDRC Phase 2 applicants, and all are unfunded finalists. Since the applications from these unfunded finalists no longer had an active NDRC web page and were not available in government archives, it is possible that these applicants had even fewer resources in development of their BCAs. As a result, this analysis may skew toward greater identification and quantification of co-benefits.

Specific challenges to coding and analyzing the data are described earlier in this section. While intending to code this universe of data into standard language, the variation of reporting styles, terminology, and redundancy across categories hindered the direct translation into a standard format. The methodology in this study resulted in aggregation of over 500 distinct phrases representing ways in which communities classified benefits into 52 benefits across four categories. Through the process of aggregation, a degree of nuance is unavoidably lost. Applicants were encouraged to be creative and the consequence of that process is that not all scenarios envisioned by the applicant teams, who intimately know the problems and possibilities in their communities, can be assigned a code. For example, Shelby County, TN identified and monetized the value of volunteer hours for the activities in its proposal. California accounted for the cost of childcare that parents would incur when schools close in response to disaster. These may be tangible and legitimate avoided costs, and this study is not intended to limit such ideas.

Two interviewees mentioned that their teams had to weigh what they understood to be the best long-term investments in these communities against the projects that would make for a compelling proposal for a competition. Outside of a competition, the cities and states might consider prioritizing different projects with a different suite of co-benefits.

Section 5: Findings & Discussion

This section includes several analyses of the BCA crosswalk, a discussion of specific findings related to the four benefit categories, and general takeaways from this research. Essentially, the findings described in this section reveal a lack of consistency in the identification, definition, and assessment methodology of resilience co-benefits. These findings reinforce current literature on resilience co-benefits, which identifies a need for standard assessment methodology.

5.1 Analyses of the BCA crosswalk

Following the methodology outlined in Section 4, I coded more than 500 benefits reported through the BCA Narrative Table of 28 NDRC Phase 2 applications into 52 benefits across four categories, including 40 resilience co-benefits:

- 12 directly demonstrating mitigation or disaster resilience value
- 12 community development
- 7 economic revitalization
- 21 environmental

The four benefit categories included a wide range of interpretation across the 28 applications. The following figures show graphical representations of the results of the BCA crosswalk. Figure 9 shows the prevalence of social, environmental, and economic co-benefits, from most to least commonly identified in the BCA Narrative Tables. Figure 10 displays the level of quantification of these benefits.

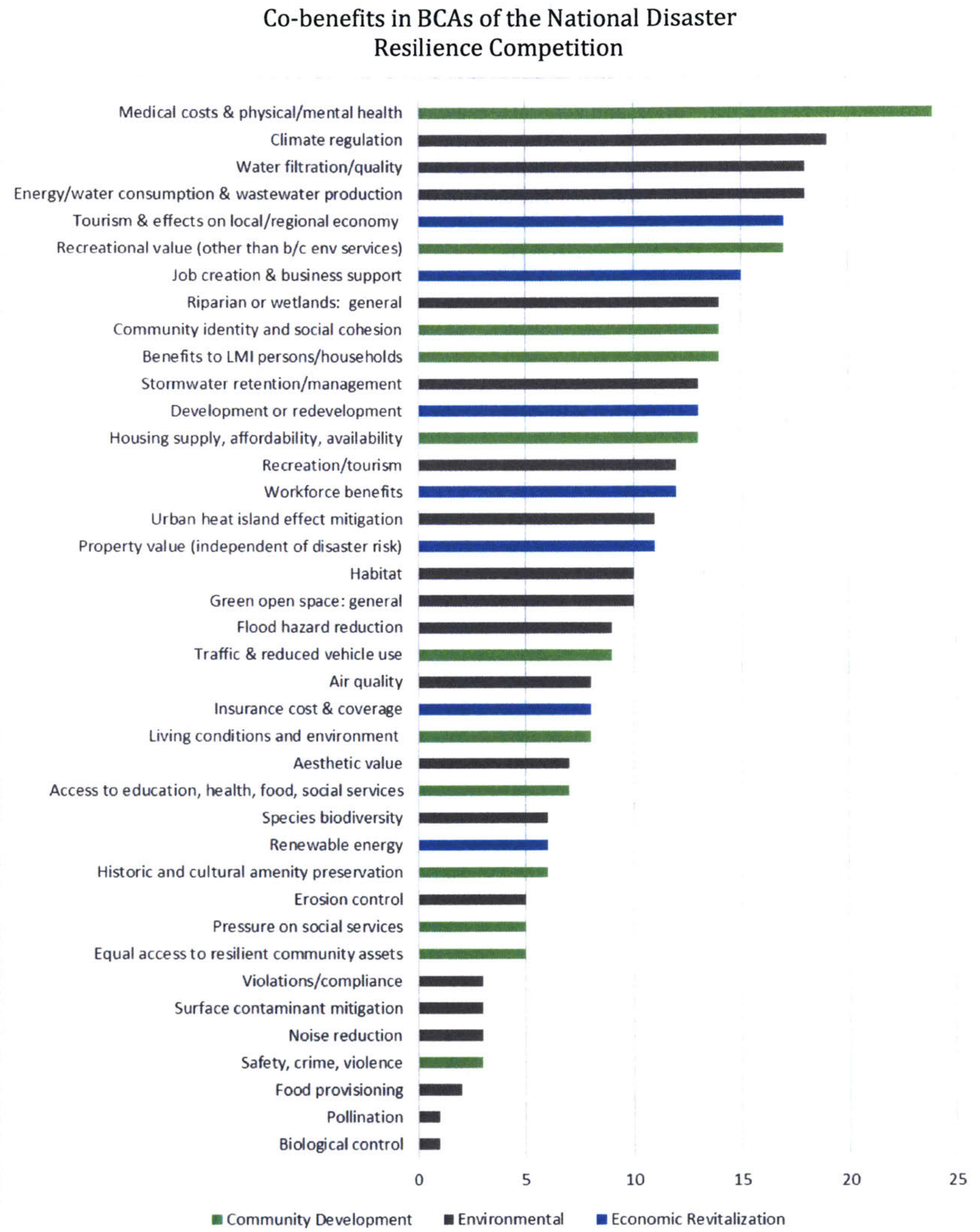

Figure 9. Results of the BCA crosswalk of the National Disaster Resilience Competition. 40 co-benefits were reported across three categories in the BCA Narrative Tables in 28 applications. Health co-benefits were identified in 24 applications.

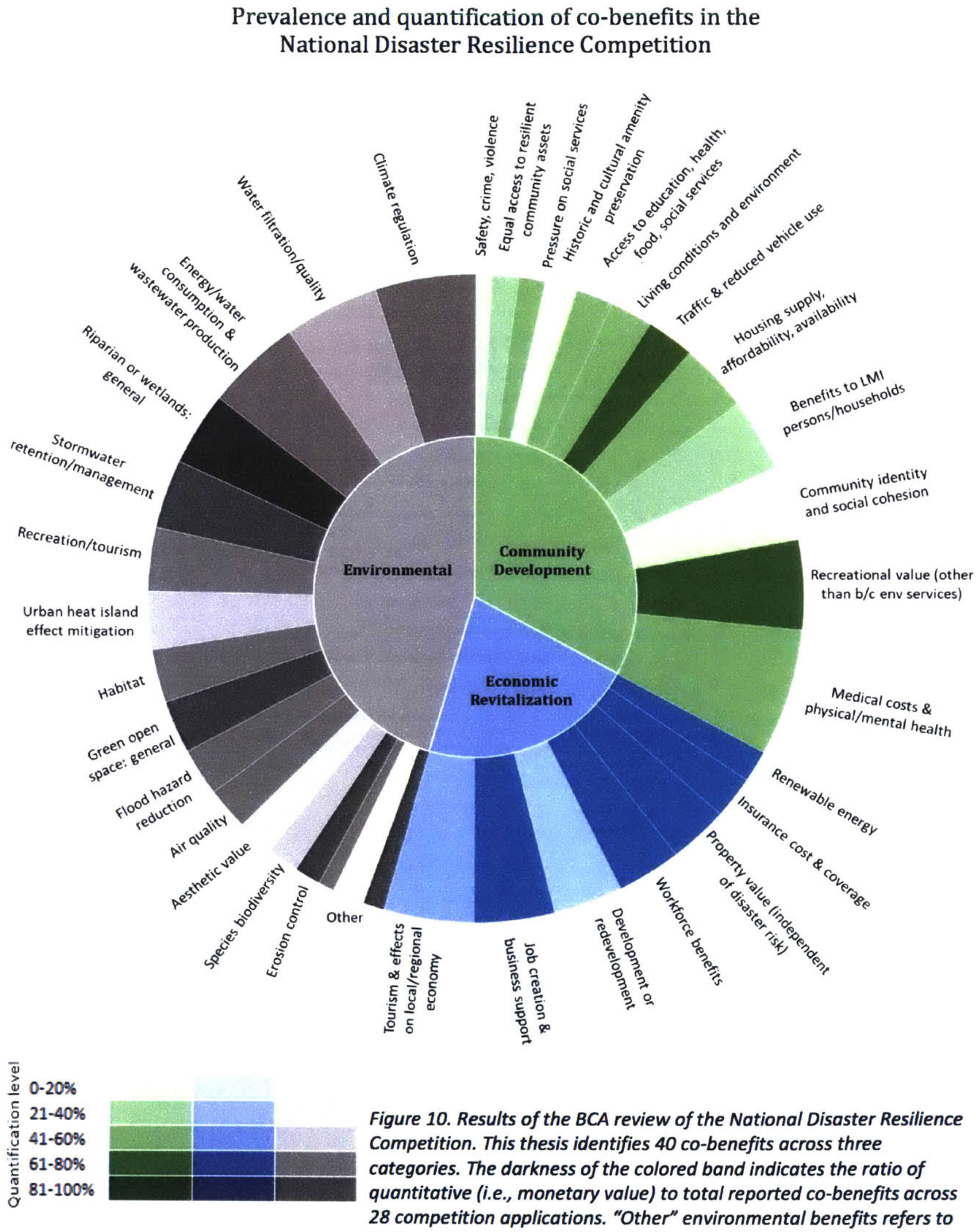

Figure 10. Results of the BCA review of the National Disaster Resilience Competition. This thesis identifies 40 co-benefits across three categories. The darkness of the colored band indicates the ratio of quantitative (i.e., monetary value) to total reported co-benefits across 28 competition applications. "Other" environmental benefits refers to biological control, pollination, and food provisioning (n=1,1,2), all assigned monetary value.

Wide range of benefit-cost ratios across applicants

In all applications included in this analysis, quantified benefits outweighed the costs of the proposal. Yet there was a wide range of reported benefit-cost ratios (BCRs) from just over 1 to over 20. This variation is less an indicator of which proposal is 'better' than it is an indicator of the inconsistency in BCA methodology among applicants. Figure 11 shows the range of BCRs across applications included in the study as well as the number of co-benefits included in each BCA. As shown, the BCR had no visible impact on funding determination. The mode of BCRs was between 1 and 2 (n=10), suggesting that inclusion of quantified co-benefits was indeed relevant to justifying project costs.

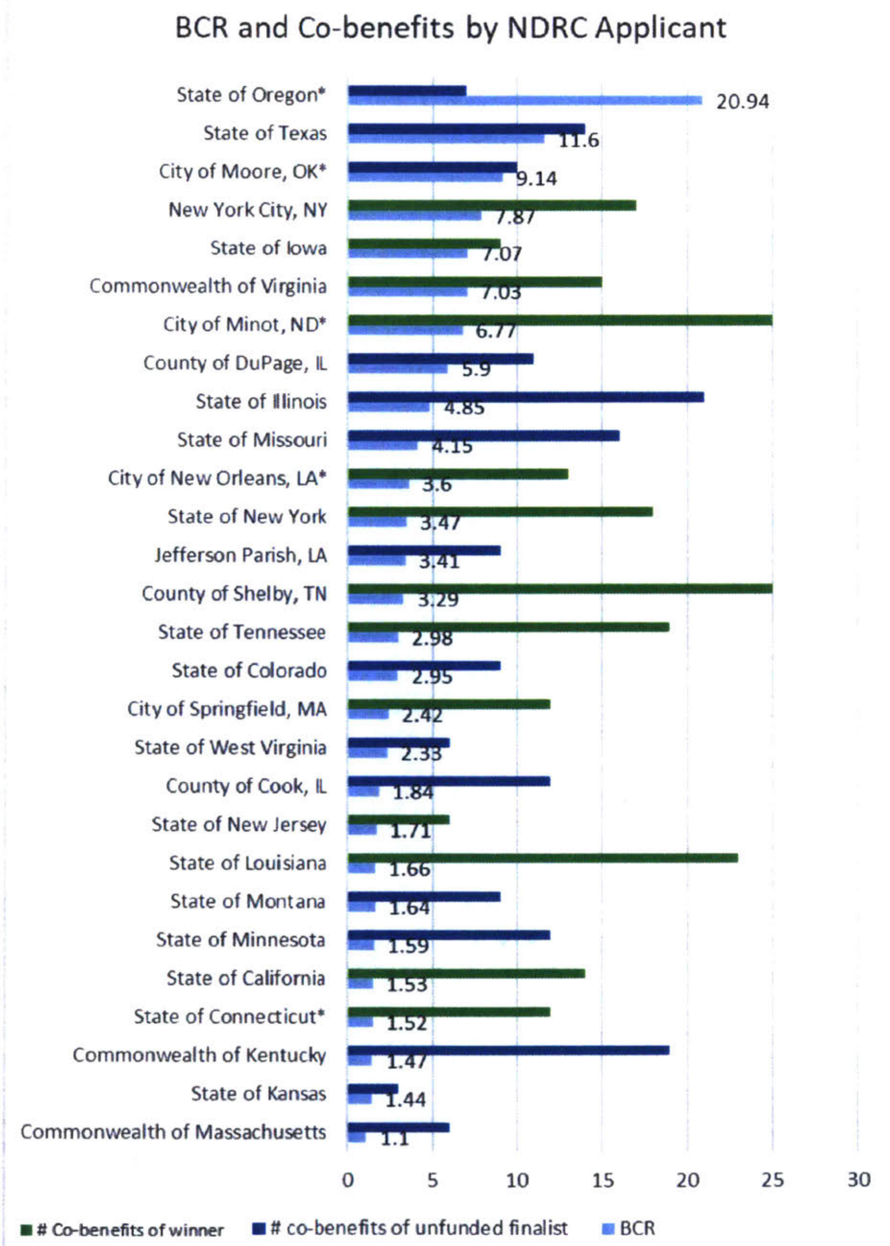

Figure 11. Benefit-cost ratios and co-benefits of NDRC Phase 2 applications analyzed in this thesis, organized by descending BCR. As shown, the BCR did not have an effect on funding determination. (*) indicates that application did not present an aggregate BCR and the largest project BCR is included.

While the BCRs did not feed directly in to application scoring, the BCR was helpful in understanding how and why applicants chose to include or not to include certain co-benefits. Oregon, for example, proposed a project with the highest BCR in the competition—20.94—yet did not win funding. The NDRC project manager in Oregon explained that while she was aware that HUD allowed co-benefits, the resiliency benefits of upgrading a bridge in the Cascadia Induction Zone obviated the need for their consideration.

> "It was quite clear from a BCA standpoint it was an extremely strong case. Without looking for softer benefits, from a pure life safety standpoint of how many people would die from not being able to cross that bridge and avoid a tsunami, we were fine. In general, we were on a very, very tight schedule, as everyone was, and we didn't fluff everything up. It was just kind of basic engineering. This is how it would help keep people alive in the community" (Wang 2018).

As it turns out, while several co-benefits were identified in the Narrative BCA Table, the resiliency benefits alone informed the 20.94 BCR. Indeed, applicants were operating on a short timeline and were given four months from start to finish for the Phase 2 application, including the BCA. However, a key message was lost in Ms. Kome's original intention for the qualitative BCA to bring forward everyday community benefits, as demonstrated by this explanation:

> "What we were trying to do was not try to recover specifically from the disasters that we didn't recover 100% from. What we were trying to do was build resilience and prepare for a future really big disaster" (Wang 2018).

Oregon was not the only applicant to exclude co-benefits from calculation of the BCR. In New Jersey, quantitative impacts related to tourism were excluded because the data were not sufficiently reliable, ensuring that "the BCR of the project is calculated rigorously while avoiding under-estimating the costs of the project" (State of New Jersey 2015). The state explained their determination in the body of the BCA attachment:

> "The positive impacts of the covered project on tourism were estimated for the study area. Since tourism data is not available at the level of individual boroughs, tourism impacts were estimated by disaggregating from Bergen County or New Jersey values. During this disaggregation process, it was not possible to account for tourism hotspots and instead an equal distribution of tourism impacts across the study area was used. While the tourism impact estimate is a defensible approximation, it is only an approximation and not of the same data quality as the rest of the BCR parameter inputs" (State of New Jersey 2015).

Similarly, Connecticut, a competition winner, chose only to include economic and risk reduction benefits. While Connecticut reported environmental and social co-benefits in the Narrative BCA Table, the state excluded them from the BCR because "although environmental benefits are resoundingly positive, their monetization is limited to a trade-off value of usable land space, which can be exceedingly speculative" (Connecticut 2015).

Wide range of benefit identification and quantification across applicants

This thesis does not include an in-depth analysis of the number of identified and quantified benefits in the BCA Narrative Table across applications for two main reasons:

1. Inclusion in the BCA Narrative Table is not a strong indicator of the quality and level of detail in the BCA appendix of the application (e.g., a table could include little information supported by sound data and in-depth narrative text).

2. The coding process as described in the Methods section removes context from individual applications.

That being the case, this section presents results by funding status (i.e., winner or unfunded finalist) as well as U.S. region.

Results by funding status

Figure 12 shows the range in benefit identification across applications. As shown, a higher number of benefits is associated with competition funding. Of the applicants in the top half of the perceived number of benefits, ten were competition winners. While this relationship is not necessarily correlative, it may indicate that applicants with a higher number of benefits produced a more in-depth application package as a whole.

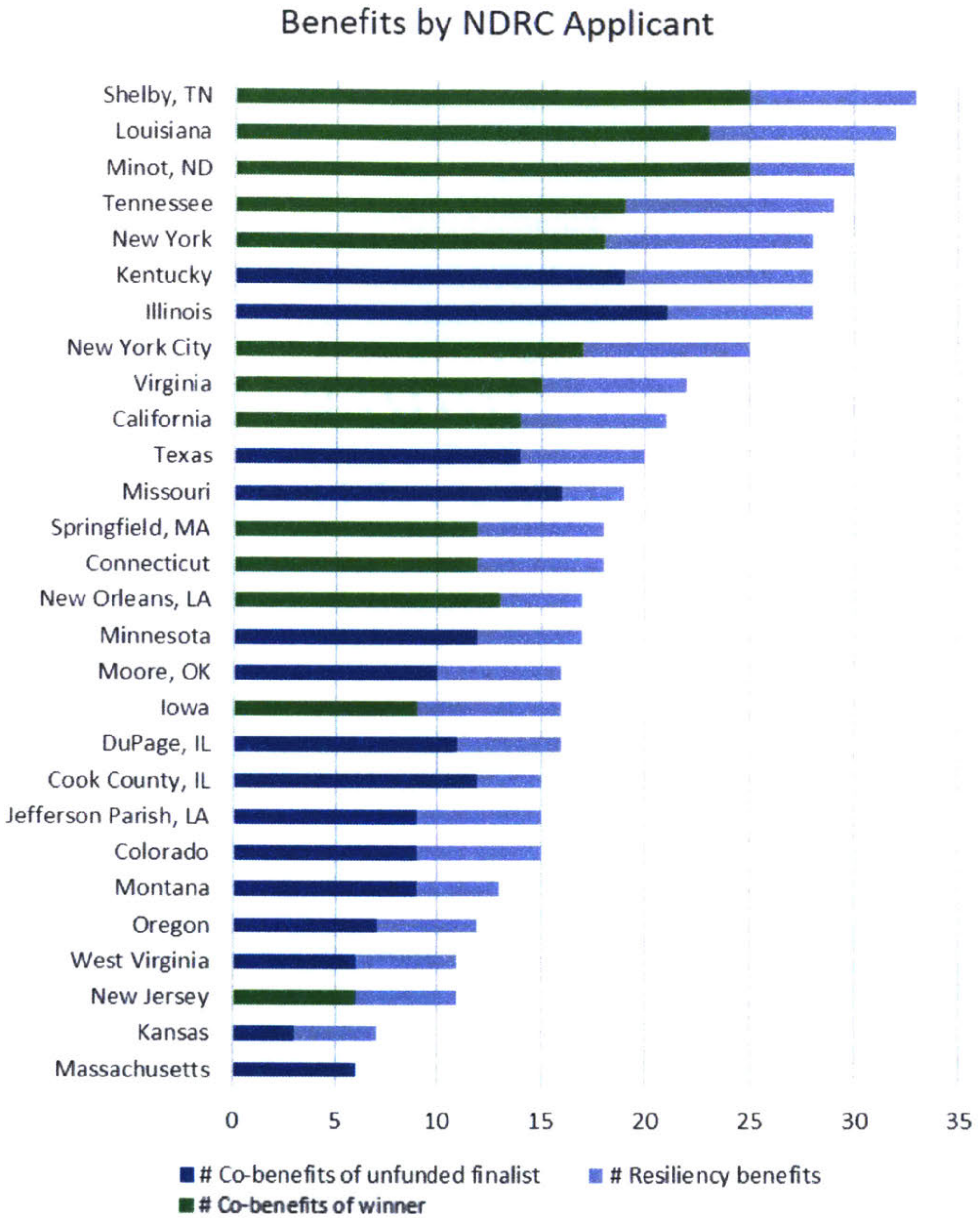

Figure 12. This figure displays the resiliency benefits and co-benefits proposed by applicant in the National Disaster Resilience Competition. As shown, a higher number of co-benefits is associated with competition funding.

The average number of resilience benefits in an application is 6 while the average number of co-benefits is 13.3. Since disaster resilience benefits are more standardized than co-benefits, there was less variation among the former. Notably, Massachusetts is shown as reporting no resilience impact from their proposed projects due to the fact that their resilience benefits related to stormwater management from trees, which were coded as environmental co-benefits.

Results by U.S. region

The tree maps in Figure 13 and Figure 14 display the hierarchy of perceived resilience co-benefits in the four U.S. Census regions. While hazards are not uniform in each region, regional differences are important to consider, such as severe winter storms occurring more frequently in the northeast and wildfire occurring more frequently in the west.

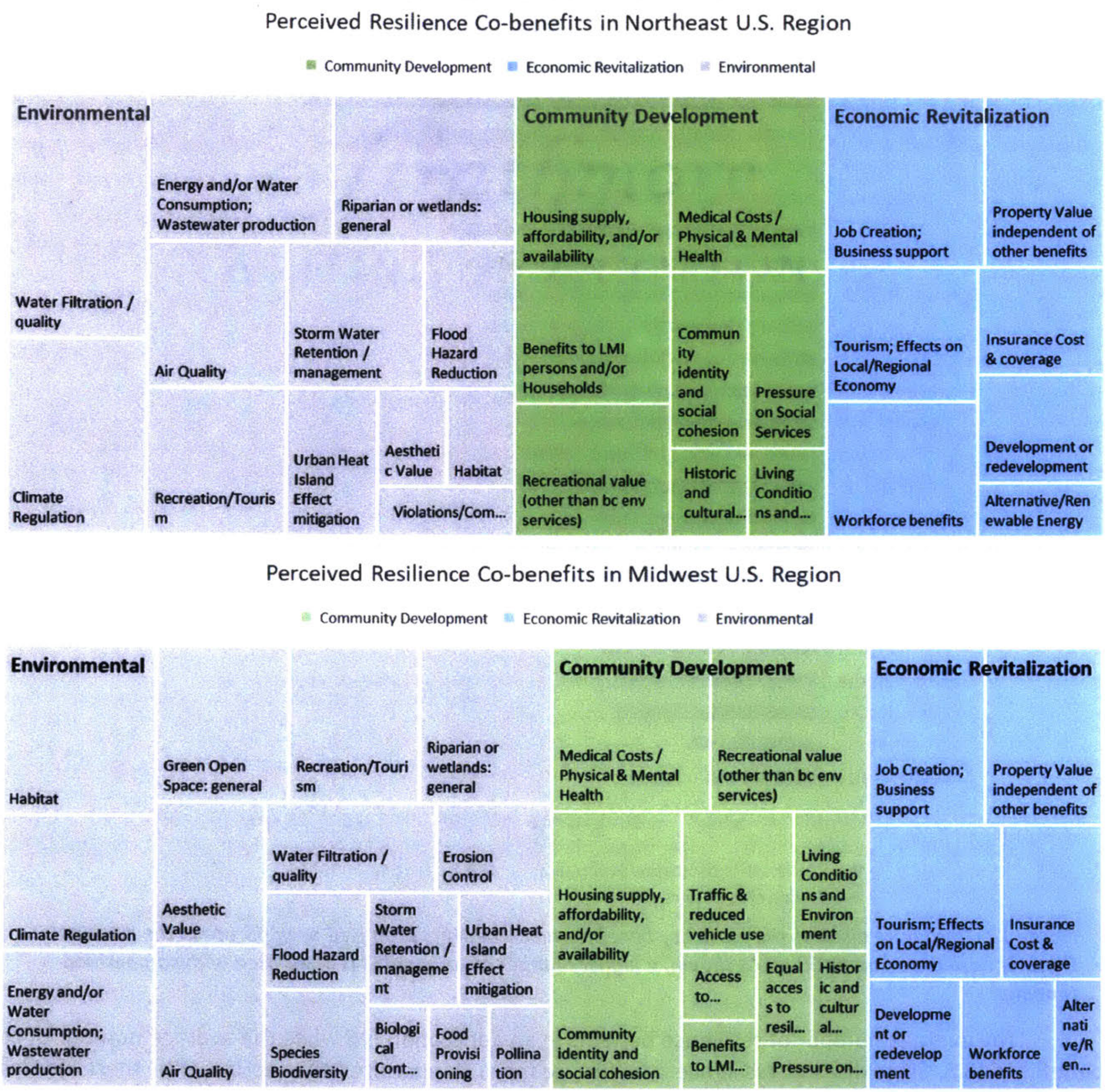

Figure 13. Tree maps of perceived resilience co-benefits in the Northeast and Midwest U.S. Census regions. Larger rectangles represent more frequently reported co-benefits. The Northeast includes applications from Connecticut, Massachusetts, New Jersey, New York, New York City, and Springfield, MA. The Midwest includes applications from Cook County, IL; DuPage, IL; Illinois; Iowa; Kansas; Minnesota; Minot, ND; and Missouri.

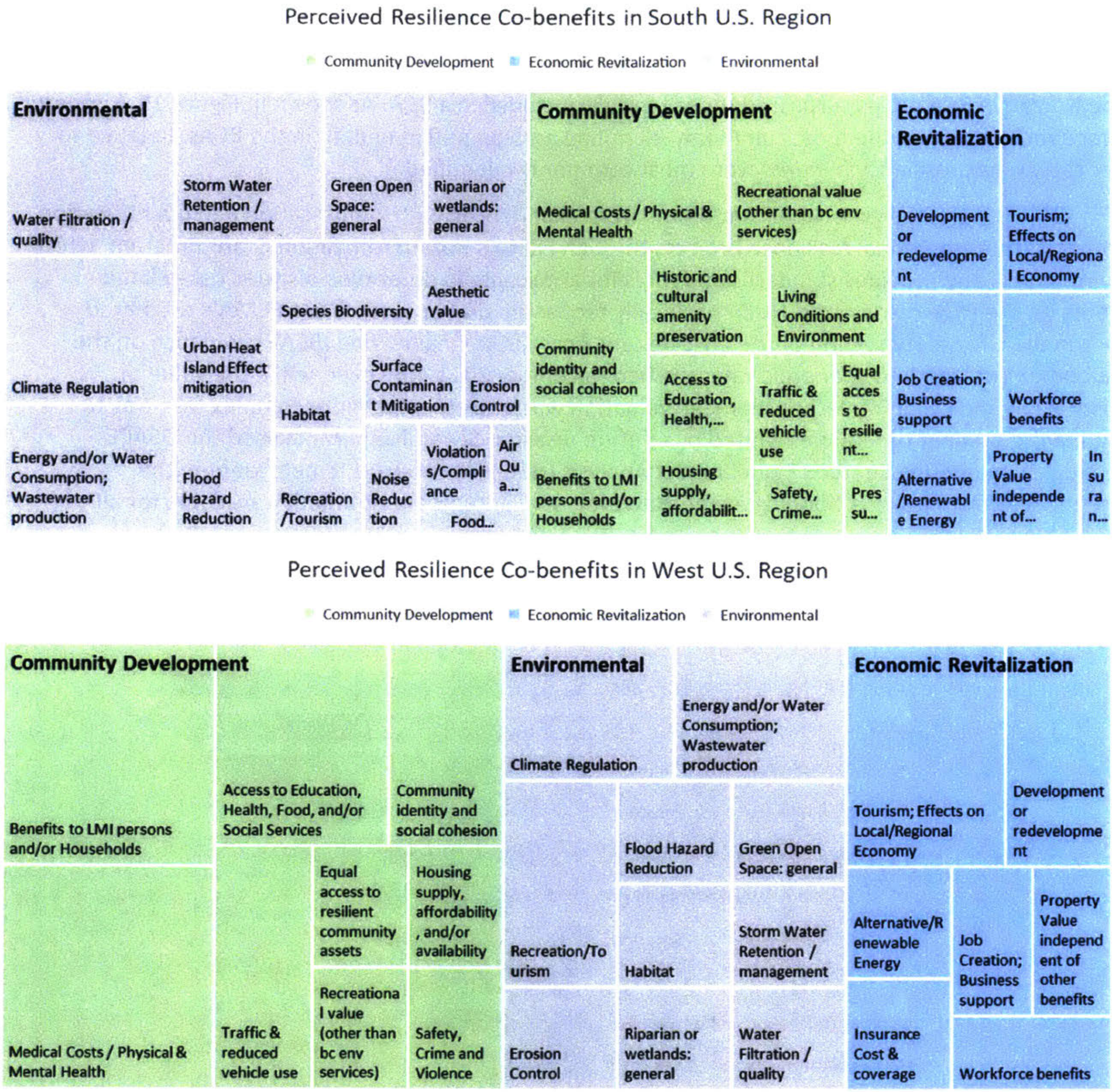

Figure 14. Tree maps of perceived resilience co-benefits in the South and West U.S. Census regions. Larger rectangles represent more frequently reported co-benefits. The South tree map includes applications from Virginia; Jefferson Parish, LA; Kentucky; Louisiana; Moore, OK; New Orleans, LA; Shelby, TN; Tennessee; Texas; West Virginia. The South tree map includes applications from Montana, Oregon, California, and Colorado.

For example, one potential pattern revealed by these tree maps is the top community development co-benefit in each region. In the northeast—the densest region in the U.S.—housing supply, affordability, and availability is a top concern. In the west, where several applicants focused on rural resilience, benefits to low- and middle-income groups was the highest reported co-benefit. The west is also the only region with more community development co-benefits than environmental co-benefits.

5.2 Resiliency value

While disaster resilience was the primary objective for the NDRC, the resilience considerations in the Narrative BCA tables surpassed those typically included in a BCA. As shown in Figure 15, *'property damage reduction'* was the most commonly identified and quantified benefit in the BCAs. Relative to other categories, resiliency benefits were most commonly quantified.

This is expected given applicant teams were experienced with identification and quantification of impacts from traditional resilience projects through FEMA's Hazard Mitigation Grant Program, which requires a BCA and provides standards and tools for applicants to determine disaster risk-related benefits. In the BCA instructions, HUD specifically requested that applicants use FEMA's estimated values in the Life Safety section of the Cost-Benefit Analysis Re-Engineering (BCAR) guidance on the development of standard economic values issued December 2011. However, while the value of statistical life and other immaterial damage valuation was available, the more complex task was to calculate the number of fatalities caused by a future disaster. Several applicants used the USACE Hydrologic Engineering Center's Flood Impact Analysis (HEC-FIA) software to help identify the consequences from a single flooding event. However, similar tools are not readily available for all disaster types.

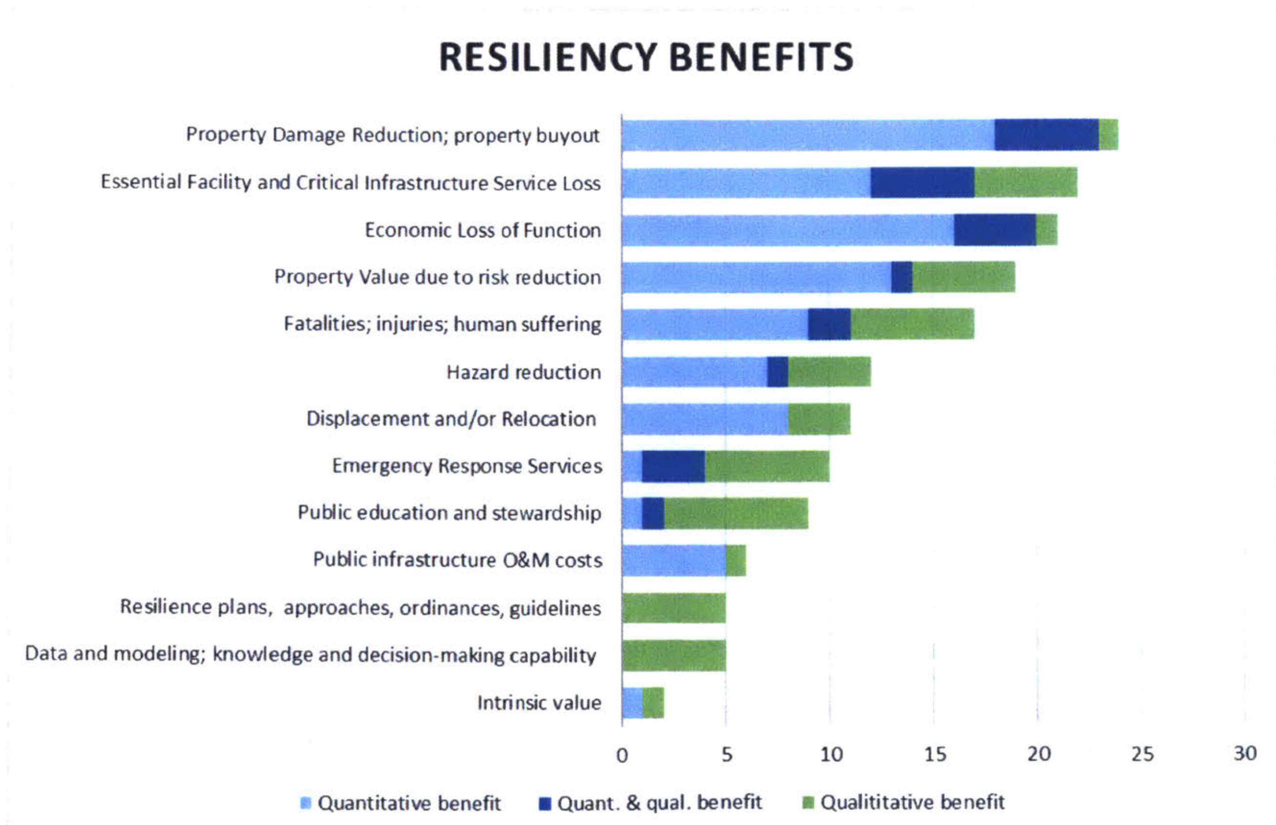

Figure 15. Resiliency benefits reported in 28 BCA Narrative Tables of the NDRC.

While *'essential facility and critical infrastructure service loss'* seems quantifiable as it relates to publicly managed systems, the benefit encompasses a variety of systems that may be impacted by a disaster. Thus assessment methodologies were not consistent. Many BCAs frequently disaggregated the operations of energy, telecommunications, water, sewer, and transportation systems to a granular level.

For example, as its only resilience benefit, Minnesota quantified the "avoided cost of temporary boiler rental to serve hospitals during future disaster" (Minnesota 2015) using actual price quotes.

Applicants used multiple perspectives to frame and quantify property damages. Reported as *avoided loss of household income*, Minot, ND, was monetized using property buyouts.

'Economic loss of function' in particular covered a wide breadth of topics, such as the opportunity cost of interrupted business, the removal of a piece of real estate from the market due to disaster impact, and lost wages due to employees' inability to reach places of employment due to road closures. While this benefit was most frequently quantified, with only 2 of 22 proposals exclusively describing *'economic loss of function'* as qualitative, the specific meaning of the phrase varied greatly. Here are some interpretations that either used the phrase directly or was coded as *'economic loss of function'*:

- Virginia described how work productivity is impacted after mental health problems resulting from disaster. Virginia and Cook County, IL both quantified using avoided mental health treatment costs.
- In Illinois, the road closures due to flooding have resulted in lost wages by the employees of Walker's Bluff who could not get to work.
- California highly disaggregating the *'economic loss of function'* benefits of fire resiliency, including *'improved stability of local ranch operations'* and childcare challenges: "Due to smoke, road closures, and safety concerns, Tuolumne schools are expected to close for at least a week in a major fire. Missed school creates a broad range of burdens, including extra child care expenses, school expenses for adjusting schedules and plans, and security and cleanup at the schools" (State of California 2015).

'Knowledge and decision-making capability' refers to the data, modeling, and systematic tools and processes that help decision-makers understand risk, plan improved disaster response, prioritize interventions, and lessen disaster impact. Specific examples include drainage basin modeling to increase knowledge of specific interventions needed to reduce flood risk; infrastructure mapping for better emergency response; and, in West Virginia, accurate and timely data provided for decision support for water infrastructure asset management will improve disaster response in quantifying damages and losses and will help identify and prioritize projects to lessen disaster impacts. Tennessee is developing a resiliency web tool that "allows local governments, businesses, and individuals to evaluate the vulnerability of physical built infrastructure to extreme weather events" (State of Tennessee 2015).

'Resilience plans, approaches, ordinances' refers to programs or policies that improve the city or state's ability to prepare or respond to disaster. For example, as part of Missouri's proposal, the state would increase the area which is required to have insurance. In West Virginia, participating communities will pass floodplain ordinances, reducing damages during subsequent storms and flood events.

'Public education and stewardship' includes process benefits of having more engaged stakeholders, designing more inclusive and effective interventions, and having a more knowledgeable and aware community, especially in the context of evacuation.

5.3 Community development co-benefits

The community development co-benefits were less frequently quantified. After all, societal concepts such as community identity and cultural preservation are not typically evaluated financially. Figure 16 displays a mixture of well-supported co-benefits such as *health* and less defined co-benefits such as *'historic and cultural amenity preservation'*.

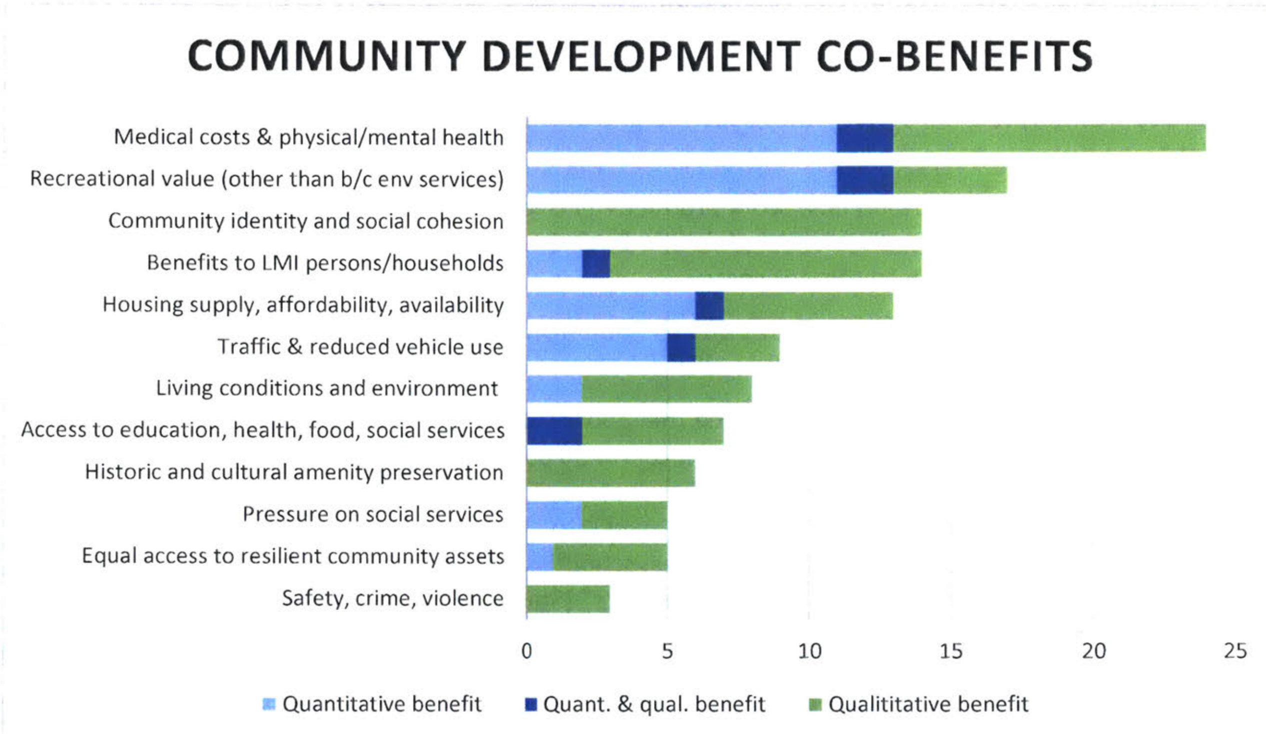

Figure 16. Community development co-benefits reported in 28 BCA Narrative Tables of the NDRC.

'Physical and mental health' was the most popular community development co-benefit, as several metrics and assessment methodologies are available through the CDBG program, FEMA HMGP, and literature to evaluate health impacts from disaster risk reduction and resilience investment. The metrics for improved health relate to reduced cost of care, which can be measured by avoided medical bills and compensation due to an increase in physical activity from new recreational opportunities as well as mental health benefits of exposure to nature and the lack of trauma during the disaster recovery process.

For physical health benefits posited to reduce health costs, one method was to 1) determine the percentage of adults, seniors, and children using population data, 2) determine the percentage of the population in each age group that meets national physical fitness guidelines, and 3) determine the increase in the number of residents meeting fitness guidelines for each age category with access to outdoor recreation opportunities. One approach to quantifying mental health benefits was to normalize the FEMA standard value and apply it to the number of residents that would be impacted by disaster if the project was not implemented, resulting in avoided mental health treatment costs over the course of 30 months, which is estimated amount of time for mental health recovery after a disaster.

'Recreational value' as a social co-benefit referred to new opportunities (usually adjacent to the built environment) such as bike and pedestrian trails, education kiosks, boardwalks, and downtown

revitalization. Virginia identified two ways to quantify recreational benefits: the Earth Economics method and the FEMA method (Commonwealth of Virginia 2015). Earth Economics uses participation rates to estimate benefits in the target area based on statewide recreation activity data, collected through an Outdoors Demand Survey. FEMA quantifies recreational benefits based on the square footage of added or improved space. For consistency with other ecosystem services, the FEMA method is coded in this study as an environmental co-benefit.

As emphasized previously, quantification is not necessarily superior to narrative description. Despite the fact that there is no one-size-fits-all metric to quantify *'community identity and social cohesion'*, fourteen applications explicitly called out benefits that strengthen the social fabric of a neighborhood and bring people together. However, the qualitative descriptions of *'community identity and social cohesion'* are so diverse that it is difficult to determine which specific intervention is most impactful. Common themes include the reduction of transient families, less home abandonment, creation of outdoor gathering spaces, and community pride. In this instance, standardization may cloud the important points.

'Safety, crime, and violence' was mentioned three times, each describing a different context. Shelby, TN proposed that "lighting additions, neighborhood watch program and reduction of blight will contribute to neighborhood revitalization" (Shelby 2015). Louisiana used an academic case study on intimate partner violence to draw the connection between hurricanes and increased levels of domestic abuse (Louisiana 2015). Colorado referred generally to population safety. Missing from these considerations, notable given the number of applications proposing greenways and open spaces, were the potential impacts of green space and new vegetation on safety according to literature. One study presented a possibility for reduced perceptions of safety (Fung and Helgeson 2017), while another study links greening programs to reduced crime rates and blight (Kondo et al. 2015).

5.4 Environmental co-benefits

Ecosystem services can provide social, environmental, and economic co-benefits. However, applicants who relied on FEMA estimates to quantify services reported them under the environmental benefit category, so Figure 17 displays results predominantly from FEMA estimates. These ecosystem services may be realized when homes are removed and land is returned to open space designations. Benefits may include flood hazard reduction; an increase in recreation and tourism; enhanced aesthetic value; and improved erosion control, air quality, and water filtration. Generally, environmental co-benefits are understood to a greater degree since they offer more measurable services to people, as reflected in the number and quantification level in this chart.

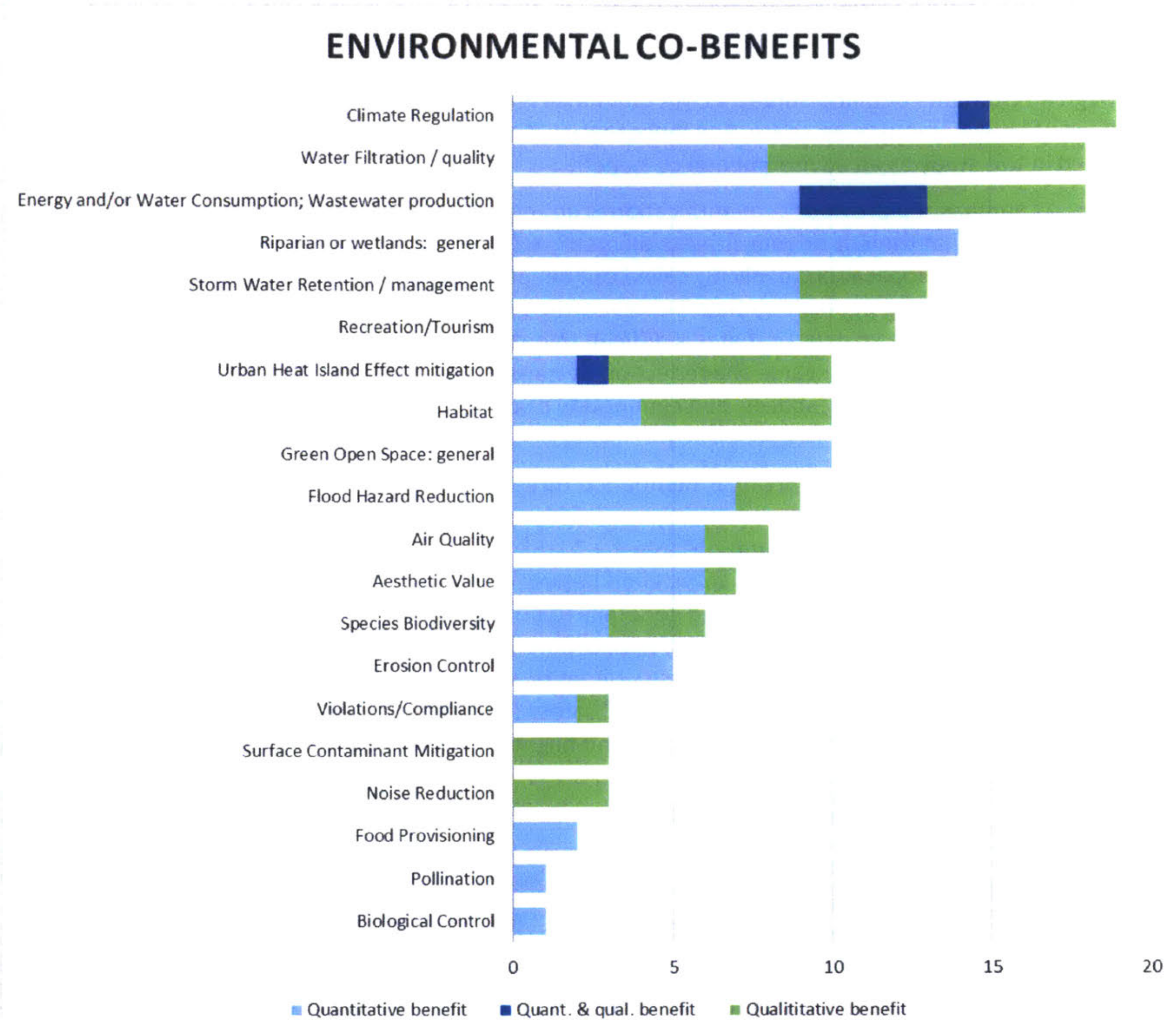

Figure 17. Environmental co-benefits as reported in BCAs across 28 National Disaster Resilience Competition applications.

The BCA is tailored to a pragmatic audience of reviewers, who seek the information needed to grade proposals based on a series of metrics. As a result, the BCAs typically captured only the utilitarian perspective of the natural environment. Ecosystem services focus on how the environment can serve humans. Quantification of ecosystem services implies that we protect the environment in order to protect ourselves. The BCA can capture reduction in spending for mental health when a greenway offers therapy to suffering adults. Yet the deep ecology perspective, a value-based system of stewardship, cannot be woven into a BCA. That said, intrinsic value, an ethical and philosophic property, was mentioned twice. Kentucky combined the benefit with biological quality in the context of stream restoration, and monetized using FEMA values. Colorado did not quantify intrinsic value for its proposed greenway improvement; however, the state suggested that the value could be expressed by residents' willingness-to-pay to live in proximity to such improvements.

As described in further detail in the Methods section, the environmental co-benefits were coded in two different ways, depending on how the applicant quantified project benefits. The general categories for *riparian or wetlands* and *green open space* were defined through use of FEMA estimates, resulting in 100% quantification in 14 and 10 BCAs, respectively. FEMA calculates ecosystem services based on the square footage of added open space. Most other BCAs also used FEMA estimates; however, they disaggregated by ecosystem service instead of land type.

68% of BCAs in this study included an emissions reductions project component, due to a range of energy and urban design interventions which result in reduced traffic, reduced vehicle use, and installation of renewable power, in addition to the FEMA '*climate regulation*' ecosystem service. While many proposals explicitly identified emissions reduction as a projected impact, others framed the '*energy consumption reduction*' co-benefit referred to sustainability and energy efficiency measures in the built environment.

Active lifestyle benefits were occasionally categorized as an environmental co-benefit, but were more commonly reported as a community development co-benefit closely linked to outdoor recreation and health. This thesis found several accepted methods to assess the recreational and aesthetic benefits of new amenities, including residents' willingness to pay for access to recreational uses and aesthetic value.

5.5 Economic co-benefits

The spread of co-benefits related to economic revitalization was the narrowest of all categories, with seven distinct impacts shown in Figure 18.

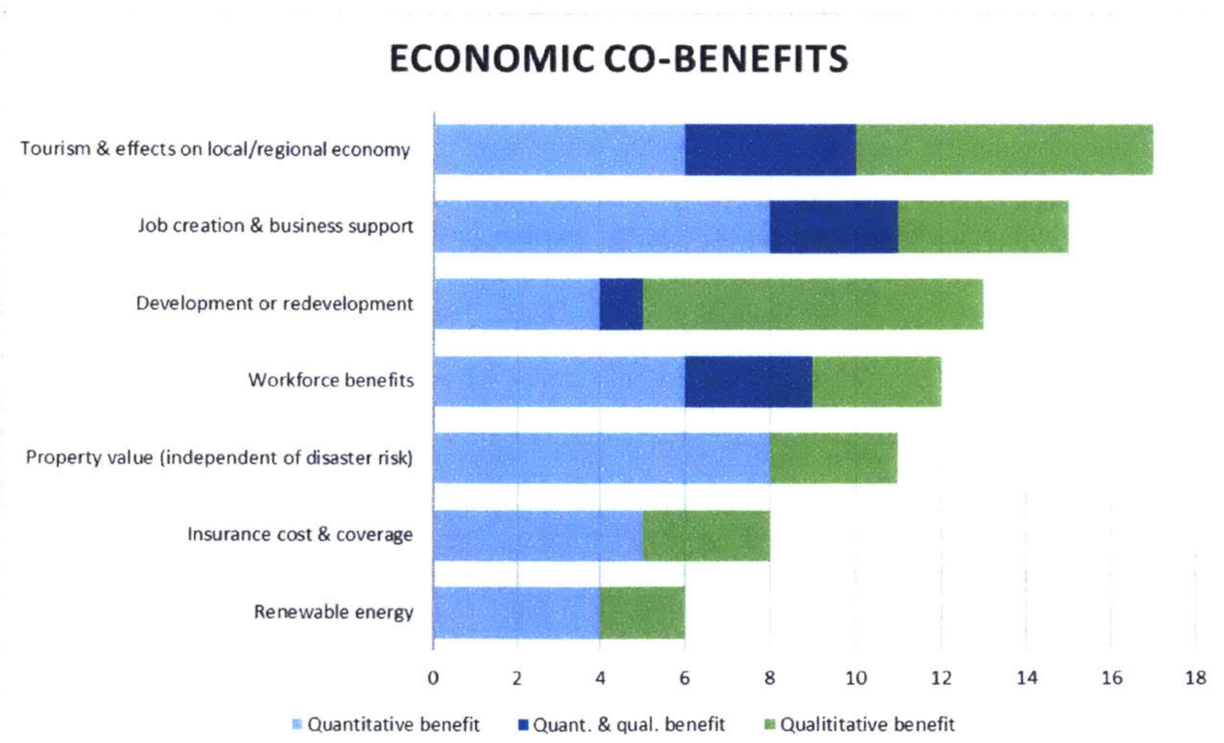

Figure 18. Economic co-benefits as identified in 28 applications of the National Disaster Resilience Competition.

'Tourism & effects on local/regional economy' is characterized by impacts which increase the level of activity or participation in the economy, through greater circulation of residents and out-of-town visitors, the economics of scale for new development, or a trickle-down effect causing workforce expansion. Occasionally, this was quantified through tax revenue of new commercial areas.

'Job creation & business support' refers to programs or projects that attract and retain employers and provide greater access or visibility to the workforce. A recurring connection was made between household income, household wealth, and economic security as well as between income distribution and per capita consumption and economic wellbeing.

'*Workforce benefits'* support employees and community members who would like to enter the workforce. These benefits can be realized through training and worker certifications (e.g., for lead abatement in Springfield, MA); classroom, apprenticeship & union programs (Missouri); youth build program with job skills training (e.g., focused on land conservation, horticulture, and watershed studies in Kentucky); and higher labor incomes, which largely drove quantification. An example of a less direct workforce benefit is Shelby, TN's suggestion that improved bicycle and pedestrian infrastructure will stimulate alternative modes of travel, resulting in a less auto-dependent workforce. According to Earth Economics, the benefit of a job created is not the full value of that job but the difference between the new job and the employee's next best opportunity. Notably, Colorado discussed engagement and training efforts which would "forge new links between local governments, non-profits and the private sector," (State of Colorado 2015) to jointly define and implement resiliency improvements.

'Development or redevelopment' typically referred to investment in new commercial opportunities on underutilized land or properties. Colorado represented this co-benefit as increase in retail sales in the area under development and monetized the co-benefit through an economic impact analysis prepared by their consultant. When development was used with reference to affordable housing, the benefit was counted toward the community development co-benefit, '*housing supply, affordability, and availability*'. Relative to the other co-benefits, development was less frequently quantified since the impacts were discussed generally with regard to economic growth.

The coding challenge regarding *'property value'* as both an economic co-benefit and resilience benefit is discussed in the Methods section. The BCAs described positive effects of streetscape interventions such as bioswales and other green infrastructure; zoning changes which spur development; and proximity or access to parks and open space. The quantification strategies include use of a local economic impact analysis, application of estimated value increases based on addition of trees and green infrastructure (2.5 to 5%, according to Cook County, IL), and estimates from a study which calculated a one-time 5% increase for properties within greenways, trails, and bike paths (Commonwealth of Kentucky 2015).

With regard to *'insurance cost & coverage',* eight applicants projected a decrease in insurance rates, as homes would be better protected against a hazard through addition of natural buffers. Missouri identified expanded insurance coverage as a major advantage of programs for rehabilitation loans, down payments, and principal cost reduction, all of which require participating homes to purchase home insurance.

'Renewable energy' economic co-benefits were reported in a variety of ways, and included credit and revenue generated from installation of alternative energy systems. This co-benefit often coincided with greenhouse gas emissions reduction. In a few cases, solar PV was incorporated into proposals for new community centers and was quantified based on electricity savings. California logged various types of revenue proposed by a proposed biomass facility, including electricity, bio char,

firewood, and compost sales. The state's subject matter experts quantified the value-add for all of these elements; for example, electricity sales uses the facility's useful life, efficiency, electricity production, and utility purchase rate (State of California 2015). Springfield's Clean Redundant Energy Sources project monetized hydropower restoration through the value of renewable energy credits. Springfield reported this economic co-benefit as '*strengthening key anchor institution*' due to projected job creation (City of Springfield, MA 2015).

5.6 General Findings & Discussion

Discretion versus standardization

An inherent tradeoff exists between discretion and standardization. If funders enforce a rigid evaluation framework, communities may be less empowered to adopt a systems perspective in considering the cascading effects of a resilience intervention. They may lose the big-picture understanding of the interconnectedness of natural landscapes, wellbeing, and economic opportunity. They may not realize the full value of the projects for which they advocate. Indeed, one of the most valuable co-benefits may be the resulting instinct of decision-makers and planners to consider social, environmental, and economic impacts of projects designed for long-term stewardship of land and people.

With no framework, communities have the freedom to demonstrate context-specific considerations—one of the original incentives for the expanded BCA. However, discretion also forces communities to iterate the BCA from scratch, investing substantial resources in reaching agreement internally on the impacts of a project and researching reliable data sources to support estimates. Furthermore, the implication may mirror those in this analysis, in which the ability to directly compare across projects and programs is limited. Especially in the context of co-benefits that do not have a standard method for quantification, such as *community cohesion,* as well as co-benefits with a variety of data sources, the BCR loses its value as a metric to aid decision-making.

An undisclosed but obvious resource disparity

In order to benchmark the level of effort to develop a BCA, it would have been instructive to have insight into the amount of resources each applicant team invested in the BCA process. In the context of limited staff time and funds to support consultants, this information could demonstrate the prohibitive cost of undertaking a comprehensive BCA and highlight the need for standardization to protect groups from having to reinvent the wheel. Conversely, the information could demonstrate the relative simplicity of compiling estimates using existing data. Regardless of the implication, federal agencies cannot set expectations for a high-quality BCA without a stronger grasp on the level of effort required to produce one.

For this thesis, information on the resources required for BCA development would help determine whether a resource disparity across applicants was significant, i.e., winners may have used more of their own funds to pay consultants to perform a robust analysis than unfunded finalists. For context, the State of Louisiana's BCA attachment alone is 422 pages. On the other end of the spectrum, one BCA was submitted in as few as ten pages.

Among other information, the application prompted applicants to include a description of the project team and any private sector or nonprofit partner contributions the BCA. Proposals complied with these instructions to varying degrees. In some cases, the BCA responsibilities of the project team were explicitly described while others did not disclose the details of BCA submission. Based on the thorough responses to this prompt, the project teams contributing to the BCA indicate resource differences. Below is an example of an explanation of the roles of the New Orleans project team.

> "This Benefit-Cost Assessment (BCA) was prepared by the City of New Orleans, Waggonner & Ball Architects, Arcadis, Asakura Robinson Company, and Earth Economics. The City of New Orleans led the preparation of the current situation and problem to be solved; valuations of flood risk reduction, aesthetic benefit to property values, and reduced maintenance costs based on subsidence. Waggonner & Ball Architects worked with the City of New Orleans to complete proposal description items for each activity and for costs and benefits; Arcadis provided cost estimation services; Asakura Robinson Company assisted with document preparation and production; Earth Economics completed valuations of environmental benefits, assisted with valuations of aesthetic economic benefits, and provided technical assistance to City staff. City of New Orleans staff were integrally involved in all document preparation processes and evaluated benefit/cost calculations for the Project and all activities" (City of New Orleans 2015).

As shown, it can take a village to create a BCA. New Orleans collaborated with a mix of local organizations which contribute context and global consultancies which have experience with valuation and estimation. As a seasoned recipient of federal disaster relief funding, the New Orleans resilience office had experience mobilizing consultants and building cross-sector partnerships. For other applicants, a wastewater engineering consultant may have been solicited for a single cost estimate with no further involvement.

The BCA processes varied as well. In California, the government team held a three-day charrette-style workshop to develop their BCA, facilitated by their consultants who had BCA experience through the Rebuild by Design competition.

Consultants were hired in either a supporting or lead role in 12 of the 13 competition winners, typically in close consultation with the applicant staff. Of these, Arcadis was involved with three winning proposals (out of four) and GCR, Earth Economics, and Waggoner & Ball Architects were each associated with two winning proposals. Other big-name consulting groups hired for the task included CDM Smith, WSP | Parsons Brinckerhoff, Louis Berger, and Sasaki. Local firms were also hired for modeling and to produce local estimates of costs and benefits.

Overall, nearly all applications relied on private and nonprofit partner support to develop the BCA. The State of New Jersey did not hire consultants for the BCA, but they did rely on estimates previously developed by project teams for the Rebuild by Design competition. Stantec was involved with three losing proposals. While it is important to reiterate that the BCA did not factor scoring, the depth and quality of the BCA may be indicative of the resources or time invested into the rest of the application.

Limited standard terminology in BCA instructions

As explained in detail in Section 4, HUD's BCA instructions were written with little attention to existing standards, leading to wide variation in language and quantification methods as well as redundancy. Applicants often used the same terminology to describe benefits as those offered as suggestions in the instructions. For example, in the state of Illinois, a co-benefit reported as *'improved living conditions'* was monetized based on FEMA estimates for environmental services from new riparian green space. Due to this variation, *'living conditions and environment'* and other co-benefits that arose from the BCA crosswalk need a more refined and standard definition, or should be disaggregated and replaced with more specific co-benefits to capture topics such as blight and neighborhood aesthetics.

Conflation of benefit categories

Another way in which the instructions may have caused confusion is the lack of differentiation between co-benefits and a resilience benefit, which in the NDRC is a direct reduction in impact of an extreme event on people and the built and natural environment. For example, a reduction of expected casualties should be a resilience benefit. However, the instructions included *'reduction in human suffering (lives lost)'* as a social benefit. In Shelby, TN, *'reduced human suffering'* referred to mental stress and anxiety as well as an increase in physical activity due to new access to natural recreational space.

In the New Orleans BCA Narrative Table, a reduction in evacuation per diems was categorized as an economic revitalization co-benefit. This benefit was monetized via cost savings of deploying emergency response crews, and refers to immediate emergency response following flooding caused by an extreme weather event (New Orleans 2015). While reliance on emergency crews for rescue and clearing debris is costly, this is a resilience benefit that is only realized in the event of a disaster. An economic co-benefit should have a more lasting impact to the economy and should occur regardless of a disaster.

Many resilience benefits and co-benefits were framed as avoided impact, damage, and cost, as opposed to the introduction of a new benefit to the intervention. For example, Virginia categorizes *'economic impacts avoided'* in the economic revitalization category, yet relies on economic impact assessment software to calculate lost economic output as a result of flood-damaged structures (Commonwealth of Virginia 2015). Through the HUD category definitions, the process of parsing out the resiliency value (i.e., reduced flood damages) from co-benefits (e.g., spending patterns in the economy) is ambiguous. More clarity and instruction are needed to emphasize the distinction between resiliency and co-benefits. The alternative is to reframe the categories themselves.

Benefits associated with existing standards were most commonly identified and quantified

Benefits associated with federal standards to fulfill other funding and reporting requirements were identified and quantified more frequently than others. Several applicants relied heavily on FEMA tools, such as the Cost-Benefit Analysis Re-Engineering (BCAR) guidance, for formulas and estimates to support otherwise difficult-to-monetize benefits. Applicants were only instructed to follow specific estimates and standards with regard to the value of statistical life and other immaterial damage valuation, for which HUD requested adherence to FEMA estimates based on Federal Aviation Administration (FAA) (2008) ratings.

Other federal or international sources of estimates and valuation guidelines include the United States Army Corps of Engineers (USACE), the U.S. Department of Transportation (DOT), World Health Organization Health Economic Assessment Tool (WHO HEAT), Bureau of Labor Statistics, EPA, and USDA. Applicants also relied on anecdotal data from past storms, local economic impact studies, white papers and journal articles, previous proposals, and pre-existing plans.

Unclear recipient of co-benefits

While this BCA is structured to showcase the benefits to society, the party realizing the benefit occasionally fluctuated between the community members within the geographic boundary of the intervention and the local government providing them with services. The reporting difference is subtle but important; for example, applications which cited an increase in property values as a co-benefit were typically calculating home values rising for homeowners. However, a few applications referred to an increase in property taxes that the local government reaps as a result of higher home assessment values. Both are valid benefits in that 1) under-resourced local governments often yearn for economic development for the objective of building a more robust tax base and 2) the homeowner's asset wealth will grow. However, the local government's ability to extract taxes from homeowners independent of an increase in their salary may conflict a societal benefit, especially for those who seek to remain in their home and enjoy the new greenway as opposed to selling their property.

Quantification is not imperative, but advantageous

Through the NDRC, HUD has demonstrated that co-benefit quantification is not necessary to make an evidence-based decision in a BCA, and that a qualitative description with a logical explanation can provide support for a project. Some co-benefits cannot not be quantified reliably, because the concepts are informed so greatly by local context and are not compatible with economic valuation. While tenure of residence and home vacancy may represent quantifiable metrics to assess changes in *'community identity and social cohesion'*, the BCAs did not reflect this consideration when describing what it means for community members to feel more connected.

However, the process of developing a narrative for and reviewing a qualitative BCA is labor-intensive. If the objective for the standardized framework is to develop metrics to compare across projects, the greater the co-benefits that can be included in calculation of the BCR, the stronger the case for the project. A shift toward quantification requires more research on the determining baseline conditions in a community and measuring change over different time horizons.

Positive bias

Vorhies and Wilkinson (2016) stated a need for a comprehensive co-benefits framework that "includes and categorises all potential positive environmental and socioeconomic impacts." However, the literature suggests that there may also be negative consequences of resiliency intervention, such as a greenway obstructing views and instilling a perception of fear or elevating homes causing further damage to surrounding homes. The BCA instructions prompted applicants to log these expected negative impacts of a project. With one exception in a single line item, all reported impacts from all BCAs included in the analysis were positive. Colorado mentioned a potential detrimental impact of their proposed statewide resilience program, forecasting an increase in city and county expenditures as the local government expands public services in newly developed and redeveloped areas. A few other applicants mentioned similar impacts, framing expanded public services as a societal benefit without taking into account the financial onus on the government.

The applications included no mention of gentrification or social justice as a potential consequence of improving urban living conditions and the related increase in property values.

Competitive grant funding and long-range planning may conflict

Unlike in a long-range planning process, applicants crafted projects that would compel reviewers. Since the funding was competitive, the proposed projects may not reflect what would otherwise be a state or city's top priority for resilience.

This has advantageous and detrimental implications. One advantage is the careful deliberation and attention toward equity—specifically on meeting the unmet needs of vulnerable populations, as opposed to infrastructure projects designed through engineering analysis alone or projects influenced by the most audible voices at public meetings. One potential disadvantage is that effective projects and programs envisioned by public servants may not have a transformative, public-facing shape that allures big spending.

From my interviews, I learned that the final proposals mask many internal negotiations among politicians, planners, and leaders in housing, public works, and health departments. Each team had to reach an agreement on the causes and projects to elevate for federal funding and those to leave in the queue for limited state and local funding. Some of these choices were made to cater specifically to HUD and the Rockefeller Center. Colorado's Iain Hyde describes this tension below:

> "Whether it's a hazard mitigation or a comprehensive planning process, it's really easy to be a little bit more high-level and less specific and concrete, where you're setting long-term goals but not so much tactical components. What the competition did was force us to do both. There was a bit of a tension between trying to come up with an idea that we thought would be competitive for a grant application as opposed to coming up with a long-term strategy that we thought would build the resilience of a community. We really had to balance that, and some cases were more successful than others. So, that's just a lesson learned, when you try to tie together long-range planning and short-term competitive grant funding at the same time" (Hyde 2018).

With specific reference to BCAs, Mr. Hyde explained that it was easier to estimate costs and phases when proposing a project, whereas "a program was a little more nebulous," (Hyde 2018), especially if specific projects had not yet been designed for the program.

Section 6: Recommendations & Looking Ahead

6.1 Recommendations

Through the NDRC, HUD began to expand the consideration of resilience co-benefits in BCA by creating the framework for the Narrative BCA Table and piloting the social, environmental, and economic co-benefit categories. This analysis identified forty co-benefits that were organized to varying degrees of success into social, environmental, and economic categories. While the three co-benefit categories may still effectively provide structure to a new method of analysis, this structure may be subject to misinterpretation without clear guidance explaining how to extract and assess impacts of an intervention. Based on the variation in interpretation of co-benefits across BCAs and reflected through the wide range of BCRs, this thesis exposes a need to clarify what the co-benefits of resilience are and to standardize their definitions.

For the federal government, the next step is to build consensus among technical experts and the public sector on an accepted understanding of the resilience co-benefits and how they might be measured in a BCA framework. In order to create an in-depth, consolidated guidance on co-benefit definitions and assessment methodologies to equip planners and policy makers to make the business case for good investments in resilience, a federal agency such as FEMA or HUD should facilitate a team of stakeholders and experts to implement the following steps:

1. Compile literature and case studies on co-benefits, ideally for multiple types of hazards, interventions, and geography.
2. Build consensus on a standard suite of co-benefits, based on evidence.
3. Define these co-benefits by the context of the intervention (e.g., urban/rural, coastal/inland, hurricane/fire).
4. Provide distinct examples of the applicability of co-benefits.
5. Produce guidelines to assess project's impact quantitatively when possible and qualitatively through a standardized approach. The guidelines can consolidate national estimates such as ecosystem service values from FEMA as well as propose suggestions for use of LIDAR, American Community Survey data, and local assessments to quantify projected local impacts of a resilience intervention.
6. Convene economists and public sector practitioners to resolve some of the inconsistencies and conflicts that may arise from the previous steps.
7. Co-create a BCA framework and guidance for resilience co-benefit assessment.

I argue that consultants also have an incentive to join this effort. Just as consultants involved in the Rebuild by Design competition were recruited by communities for the NDRC, the consultants who worked on BCAs for this competition (e.g., AECOM, Arcadis, Stantec, GCR) are now well-positioned to become the leaders in resilience BCA. If these groups continue to use their own interpretations of co-benefit concepts, they run the risk of unknowingly developing of a language that is inconsistent with other practitioners and the government agencies which supply the work upstream. Contributing to development of unified definitions of co-benefits can demonstrate to potential clients that they are indeed at the forefront of their practice.

The process recommended above may take years to produce a standardized and user-friendly framework for communities to follow. In the meantime, local community development, planning, and public agencies should use proposals from competition winners and results in this thesis to stimulate a conversation in the near-term about the main priorities, risks, and opportunities in their community. Especially in areas without a history of extreme weather events, local government actors should take steps to evaluate their risks in the context of climate change and begin the process of designing projects that achieve community goals while offering protection from hazards.

Table 7 below presents a list of key co-benefits based on the BCA crosswalk that can serve as the basis for initial discussions about co-benefit identification, definition, and assessment for resilience co-benefits.

Table 7. 33 key co-benefits and potential sources of quantification.

Co-benefit	Potential reputable sources of quantification
Community Development Category	
Access to education, health, food, social services	
Community identity and social cohesion	Park Value Calculator (PVC)
Historic and cultural amenity preservation	
Housing supply, affordability, availability	State-per unit household rent savings in new affordable housing
Medical costs & physical/mental health	FEMA BCA treatment cost/person
Neighborhood beautification	
Pressure on social services	
Recreational value (other than from environmental services)	
Safety, crime, violence	
Traffic & reduced vehicle use	DOT Valuation of Travel Time in Economic Analysis
Economic Revitalization Category	
Development or redevelopment	
Insurance cost & coverage	
Job creation & business support	IMPLAN impact data and analytical software
Property value (independent of disaster risk)	-National Recreation and Park Association Park Values Calculator -U.S. Forest Service i-Tree Planting Calculator
Renewable energy	
Tourism & effects on local/regional economy	
Workforce benefits	IMPLAN impact data and analytical software
Environmental Category	
Aesthetic value	FEMA Mitigation Policy
Air quality	-FEMA Mitigation Policy -U.S. Forest Service i-Tree Planting Calculator

Co-benefit	Potential reputable sources of quantification
	-United States Interagency Working Group on Social Cost of Carbon
Biological control	FEMA Mitigation Policy
Climate regulation	-FEMA Mitigation Policy -EPA Social Cost of Carbon -U.S. Forest Service i-Tree Planting Calculator -U.S. Department of Agriculture in its 2006 Report: Methods for Calculating Forest Ecosystem and Harvested Carbon with Standard Estimates for Forest Types of the United States -Earth Economics Carbon Database Tool
Energy/water consumption & wastewater production	Center for Neighborhood Technology Green Infrastructure Guide
Erosion control	FEMA Mitigation Policy
Flood hazard reduction	
Food provisioning	
Habitat & Species biodiversity	
Noise reduction	
Pollination	
Recreation	- FEMA Mitigation Policy - U.S. Forest Service i-Tree Planting Calculator
Stormwater retention/management	- FEMA Mitigation Policy - U.S. Forest Service i-Tree Planting Calculator - Center for Neighborhood Technology Green Infrastructure Guide
Surface contaminant mitigation	
Urban heat island effect mitigation	
Violations/compliance	
Water filtration/quality	FEMA Mitigation Policy

6.2 Looking ahead

As the popularity of a BCA with co-benefits rises, we need a robust framework that does not require communities with limited resources to start from scratch. In a Rockefeller Center blog post, authors write:

> "Going beyond assessing resilience relative to an ideal state, towards actually measuring and quantifying changes in resilience is even more practically and conceptually challenging. A measurement approach would need to account for different time horizons, changing baseline conditions over time, and would need to integrate measurement methodologies from a variety of different disciplines" (Rumbaitis Del Rio, Junmookda, and Koopthavonrerk 2015).

The BCA in the NDRC was proof of concept, and the hope is that one day a BCA that incorporates co-benefits can be used as a tool to compare and prioritize projects in order to make decisions about the best use of limited resources. It is not likely that a competition like the NDRC will be run in the foreseeable future. However, the BCA did trigger new action at the federal level with a potentially greater impact. First, FEMA has somewhat adopted the BCA for the Hazard Mitigation Grant Program (HMGP), and Ms. Kome would be "deeply surprised if grantees weren't taking notes" from the winners of the NDRC (Kome 2018).

On February 9, 2018, Congress released a Federal Register notice appropriating $28 billion for HUD's CDBG Disaster Recovery Program. Of that, $7.4 billion is earmarked for territories affected by hurricanes Maria and Harvey while at least $12 billion will be allocated through grants (Government Publishing Office 2018). For context, in its 30-year history, the FEMA HMGP has awarded approximately $15 billion, making the CDBG-DR Program bigger in one year than FEMA's HMGP has ever been. According to Ms. Kome, the allocation rules of the $12 billion have not been written yet, but are likely to borrow from the NDRC BCA.

Starting in May 2018, competition winners have begun to report updates and track progress in HUD's new web portal. HUD is also working on a Business Intelligence Tool that will integrate the data from winners. Soon HUD will have a collection of hard data on co-benefits, to the extent that competition winners are able to track them. This may encourage greater public and private investment in resilience, transforming a community's social and ecological goals into economic incentives. Instead of extrapolating data from climate change adaptation studies or developing contexts, researchers may soon be able to use competition data to base new estimates for qualitative co-benefits.

Yet the CDBG-DR appropriation remains limited by retrospection. While this competition and the CDBG-DR program as a whole only consider communities that have already suffered and continue to have unmet need, other communities might be the most at-risk moving forward. Ms. Naramore explained that while devastation caused by disaster has brought resilience to the forefront of conversation, "the real success would be getting jurisdictions who have not had a disaster to get out in front and start doing this work" (Naramore 2018). Success will be achieved when investment in resilience becomes common practice because it pays off daily.

References

"20 Years Stronger - Downtown Development | City of Grand Forks, ND." n.d. Accessed April 23, 2018. http://www.grandforksgov.com/government/city-departments/public-information-center/20-years-stronger-v/20-years-stronger-downtown-development#ad-image-2.

"20 Years Stronger - Flood Protection | City of Grand Forks, ND." n.d. Accessed April 23, 2018. http://www.grandforksgov.com/government/city-departments/public-information-center/20-years-stronger-flood-protection#ad-image-8.

"1997 Grand Forks Flood By The Numbers | FEMA.gov." n.d. Accessed April 22, 2018. https://www.fema.gov/1997-grand-forks-flood-numbers.

Alexander, D. E. 2013. "Resilience and Disaster Risk Reduction: An Etymological Journey." *Natural Hazards and Earth System Science* 13 (11): 2707–16. https://doi.org/10.5194/nhess-13-2707-2013.

Allen, Myles. 2003. "Liability for Climate Change." Comments and Opinion. Nature. February 27, 2003. https://doi.org/10.1038/421891a.

"ATSDR - The Social Vulnerability Index (SVI) - Home Page." n.d. Accessed May 10, 2018. https://svi.cdc.gov/.

Barker, Terry. 2017. "The Economics of Avoiding Dangerous Climate Change." In *Green Economy Reader*, edited by Stanislav Shmelev, 6:237–63. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-38919-6_11.

Cameron, John, and World Health Organization, eds. 2011. *Valuing Water, Valuing Livelihoods: Guidance on Social Cost-Benefit Analysis of Drinking-Water Interventions, with Special Reference to Small Community Water Supplies*. London: New York : IWA Publishing : World Health Organization.

Committee on Extreme Weather Events and Climate Change Attribution, Board on Atmospheric Sciences and Climate, Division on Earth and Life Studies, and National Academies of Sciences, Engineering, and Medicine. 2016. *Attribution of Extreme Weather Events in the Context of Climate Change*. Washington, D.C.: National Academies Press. https://doi.org/10.17226/21852.

Desai, B., A. Maskrey, Pascal Peduzzi, Andréa De Bono, and Christian Herold. 2015. "Making Development Sustainable: The Future of Disaster Risk Management, Global Assessment Report on Disaster Risk Reduction." https://archive-ouverte-unige-ch.libproxy.mit.edu/unige:78299.

"ESG Sustainable Impact Metrics - MSCI." n.d. Accessed May 10, 2018. https://www.msci.com/esg-sustainable-impact-metrics.

Federal Emergency Management Agency. 2009. "Design Considerations for Improving Critical Facility Functionality during Flood Events." October 2009. https://www.floods.org/ace-files/documentlibrary/Whitepapers/ASFPM_Critical_Facilties_and_Flood_Risk_Final_Feb_2011.pdf.

FEMA. 2009. "Benefit Cost Analysis Reference Guide." https://www.fema.gov/media-library/assets/documents/18870.

Fung, Juan F, and Jennifer F Helgeson. 2017. "Defining the Resilience Dividend: Accounting for Co-Benefits of Resilience Planning." NIST TN 1959. Gaithersburg, MD: National Institute of Standards and Technology. https://doi.org/10.6028/NIST.TN.1959.

Government Publishing Office. 2018. "Federal Register, Volume 83 Issue 28." February 9, 2018. https://www.gpo.gov/fdsys/pkg/FR-2018-02-09/html/2018-02693.htm.

Handforth-Kome, Jessie. 2018. "Interview Follow-up with HUD: NDRC Phase 2 Benefit-Cost Analysis," April 4, 2018.

Howe, Peter D., Hilary Boudet, Anthony Leiserowitz, and Edward W. Maibach. 2014. "Mapping the Shadow of Experience of Extreme Weather Events." *Climatic Change* 127 (2): 381–89. https://doi.org/10.1007/s10584-014-1253-6.

HUD. 2001. "Guide to National Objectives and Eligible Activities for CDBG Entitlement Communities - Chapter 2: Categories of Eligible Activities." https://www.hudexchange.info/onecpd/assets/File/CDBG-National-Objectives-Eligible-Activities-Chapter-2.pdf.

———. 2014. "NDRC Appendix H Phase 2 BCA Instructions."

———. 2015. "NDRC Frequently Asked Questions." March 19, 2015. https://www.hudexchange.info/onecpd/assets/File/National-Disaster-Resilience-Competition-FAQs.pdf.

———. 2016. "HUD's Office of Community Planning and Development (CPD) Update: September 2016." September 2016. https://www.hudexchange.info/news/huds-cpd-update-september-2016/#Kome.

———. n.d. "CDBG-DR Fact Sheet.pdf." Accessed April 25, 2018a. https://www.hudexchange.info/resources/documents/CDBG-DR-Fact-Sheet.pdf.

———. n.d. "U.S. Department of Housing and Urban Development Mission." Accessed March 10, 2018b. https://www.hud.gov/about/mission.

HUD Exchange. n.d. "National Disaster Resilience." Accessed April 8, 2018. https://www.hudexchange.info/programs/cdbg-dr/resilient-recovery/.

Institute for the Environment. 2013. "Kinston, North Carolina Case Study." 2013. https://www.eli.org/sites/default/files/eli-pubs/kinstoncasestudy.pdf.

J. Kellett, and A. Caravani. 2013. "Financing Disaster Risk Reduction - A 20 Year Story of International Aid." Global Facility for Disaster Reduction and Recovery.

Kahlmeier, Sonja, Thomas Götschi, Nick Cavill, Alberto Castro Fernandez, Christian Brand, David Rojas Rueda, and James Woodcock. 2017. "Health Economic Assessment Tool (HEAT) for Walking and for Cycling. Methods and User Guide on Physical Activity, Air Pollution, Injuries and Carbon Impact Assessments." World Health Organization. http://www.euro.who.int/__data/assets/pdf_file/0010/352963/Heat.pdf?ua=1.

Khew, Yu Ting Joanne, Marcin Pawel Jarzebski, Fatma Dyah, Ricardo San Carlos, Jianping Gu, Miguel Esteban, Rafael Aránguiz, and Tomohiro Akiyama. 2015. "Assessment of Social Perception on the Contribution of Hard-Infrastructure for Tsunami Mitigation to Coastal Community Resilience after the 2010 Tsunami: Greater Concepcion Area, Chile." *International Journal of Disaster Risk Reduction* 13 (September): 324–33. https://doi.org/10.1016/j.ijdrr.2015.07.013.

Knight-Lenihan, Stephen. 2016. "Benefit Cost Analysis, Resilience and Climate Change." *Climate Policy* 16 (7): 909–23. https://doi.org/10.1080/14693062.2015.1052957.

Kondo, Michelle C., Sarah C. Low, Jason Henning, and Charles C. Branas. 2015. "The Impact of Green Stormwater Infrastructure Installation on Surrounding Health and Safety." *American Journal of Public Health* 105 (3): e114–21. https://doi.org/10.2105/AJPH.2014.302314.

Larsen, Rasmus Klocker, Emma Calgaro, and Frank Thomalla. 2011. "Governing Resilience Building in Thailand's Tourism-Dependent Coastal Communities: Conceptualising Stakeholder Agency in Social–ecological Systems." *Global Environmental Change* 21 (2): 481–91. https://doi.org/10.1016/j.gloenvcha.2010.12.009.

Maskrey, Andrew. 1989. *Disaster Mitigation: A Community Based Approach*. Development Guidelines 3. Oxford: Oxfam.

Naramore, Sue. 2018. Interview with California Office of Community Development for NDRC Phase 2 Benefit-Cost Analysis.

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

Raymond, Christopher M, and Centre for Ecology and Hydrology (Great Britain). 2017. *An Impact Evaluation Framework to Support Planning and Evaluation of Nature-Based Solutions Projects: Prepared by the EKLIPSE Expert Working Group on Nature-Based Solutions to Promote Climate Resilience in Urban Areas*.

Rumbaitis Del Rio, Cristina, Kimberly Junmookda, and Phiradol Koopthavonrerk. 2015. "Are We Resilient Yet?" The Rockefeller Foundation. March 23, 2015. https://www.rockefellerfoundation.org/blog/are-we-resilient-yet/.

Sagoff, Mark. 2008. *The Economy of the Earth: Philosophy, Law, and the Environment*. 2nd ed. Cambridge Studies in Philosophy and Public Policy. Cambridge ; New York: Cambridge University Press.

Stocker, Thomas, ed. 2014. *Climate Change 2013: The Physical Science Basis: Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. New York: Cambridge University Press.

Stott, Peter A., D. A. Stone, and M. R. Allen. 2004. "Human Contribution to the European Heatwave of 2003." *Nature* 432 (7017): 610–14. https://doi.org/10.1038/nature03089.

Surminski, Swenja, and Thomas Tanner, eds. 2016. *Realising the "Triple Dividend of Resilience."* Climate Risk Management, Policy and Governance. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-40694-7.

Tanner, Thomas, Swenja Surminski, Emily Wilkinson, Robert Reid, Jun Rentschler, Sumati Rajput, and Emma Lovell. 2016. "The Triple Dividend of Resilience—A New Narrative for Disaster Risk Management and Development." In *Realising the "Triple Dividend of Resilience,"* 1–29. Climate Risk Management, Policy and Governance. Springer, Cham. https://doi.org/10.1007/978-3-319-40694-7_1.

Tomczyk, Aleksandra M., Piran C.L. White, and Marek W. Ewertowski. 2016. "Effects of Extreme Natural Events on the Provision of Ecosystem Services in a Mountain Environment: The Importance of Trail Design in Delivering System Resilience and Ecosystem Service Co-Benefits." *Journal of Environmental Management* 166 (January): 156–67. https://doi.org/10.1016/j.jenvman.2015.10.016.

UNISDR. 2009. "2009 UNISDR Terminology on Disaster Risk Reduction." 2009. https://www.unisdr.org/we/inform/publications/7817.

USGS. 2013. "Aftermath of Hurricane Fran in North Carolina--Preliminary Data on Flooding and Water Quality." January 10, 2013. https://pubs.usgs.gov/of/1996/ofr96-499/.

Vorhies, Francis, and Emily Wilkinson. 2016. "Co-Benefits of Disaster Risk Management: The Third Dividend of Resilience." In *Realising the "Triple Dividend of Resilience,"* 55–72. Climate Risk Management, Policy and Governance. Springer, Cham. https://doi.org/10.1007/978-3-319-40694-7_3.

Wang, Yumei. 2018. Interview with project manager for NDRC application in Oregon.

Wilkinson, Emily. 2012. "Transforming Disaster Risk Management: A Political Economy Approach." *London: Overseas Development Institute*.

Appendix 1: Full BCA crosswalk

Category	Benefit	California	Colorado	Virginia	Connecticut	Cook County, IL	DuPage, IL	Illinois	Iowa
Community Development	Access to Education, Health, Food, and/or Social Services	0/1	0						
	Benefits to LMI persons and/or Households	0	0		1			0/1	
	Community identity and social cohesion	0	0		0			0	0
	Equal access to resilient community assets	1						0	
	Historic and cultural amenity preservation			0	0				
	Housing supply, affordability, and/or availability			0	1	1			1
	Living Conditions and Environment				1		0	1	
	Medical Costs / Physical & Mental Health	1	0	1		1	0	1	1
	Pressure on Social Services								
	Recreational value (other than bc env services)		0	1	1	1	1	0/1	
	Safety, Crime and Violence		0						
	Traffic & reduced vehicle use	0					1	0/1	
Economic Revitalization	Alternative/Renewable Energy	1							
	Insurance Cost & coverage	0			1		1	1	
	Job Creation; Business support	0/1		1	0/1	1		1	
	Property Value independent of other benefits		1			1		1	
	Development or redevelopment		1	1	0	1		0/1	
	Tourism; Effects on Local/Regional Economy	1	1	0				0/1	0
	Workforce benefits	0/1		1					
Environmental	Aesthetic Value			1		1		0	
	Air Quality				1	1	0		
	Biological Control								
	Climate Regulation	1				1		1	
	Energy and/or Water Consumption; Wastewater production	0				1			1
	Erosion Control								1
	Flood Hazard Reduction							0	
	Food Provisioning								
	Green Open Space: general			1			1	1	
	Habitat	0				1	0		0
	Noise Reduction								
	Pollination								
	Recreation/Tourism		1		1		0	0	
	Riparian or wetlands: general			1			1	1	
	Species Biodiversity			1				0	1
	Storm Water Retention / management			0				0	
	Surface Contaminant Mitigation								
	Urban Heat Island Effect mitigation			0			0	1	
	Violations/Compliance								
	Water Filtration / quality	0		1	0	1			1
Resiliency	Data and modeling; knowledge and decision-making capability								
	Displacement and/or Relocation		1	1	1				1
	Economic Loss of Function	0/1	1	1	1	1	1	1	1
	Emergency Response Services	0/1		0				0	
	Essential Facility and Critical Infrastructure Service Loss	0/1	1	1	1		0	0/1	1
	Fatalities; injuries; human suffering	1		1	1			0	1
	Hazard reduction						0	0/1	1
	Intrinsic value		1						
	Property Damage Reduction; property buyout	1	1	1	1	1	1	0/1	1
	Property Value due to risk reduction	1		1	1	1	1	1	1
	Public education and stewardship								
	Public infrastructure O&M costs								
	Resilience plans, approaches, ordinances, guidelines				0				

Category	Benefit	Jefferson	Kansas	Kentucky	Louisiana	Massachı	Minnesot	Minot, NI	Missouri
Community Development	Access to Education, Health, Food, and/or Social Services			0	0/1			0	
	Benefits to LMI persons and/or Households			0					0
	Community identity and social cohesion			0	0			0	0
	Equal access to resilient community assets								0
	Historic and cultural amenity preservation				0		0		
	Housing supply, affordability, and/or availability				0		1	0	0
	Living Conditions and Environment			0					0
	Medical Costs / Physical & Mental Health	1		0	0			0	0
	Pressure on Social Services				0		1		0
	Recreational value (other than bc env services)	1		0	1		1	1	
	Safety, Crime and Violence				0				
	Traffic & reduced vehicle use			1	0			1	0
Economic Revitalization	Alternative/Renewable Energy						1		
	Insurance Cost & coverage							1	0
	Job Creation; Business support				0		1	1	1
	Property Value independent of other benefits		0	1		1		1	
	Development or redevelopment			0	0				
	Tourism; Effects on Local/Regional Economy			1	0		1	1	
	Workforce benefits			0	1		1	1	0
Environmental	Aesthetic Value				1			1	
	Air Quality					1		1	0
	Biological Control							1	
	Climate Regulation	1		1	0/1	1	1	1	0
	Energy and/or Water Consumption; Wastewater production	1			1	1	0/1	1	1
	Erosion Control			1	1			1	
	Flood Hazard Reduction	1		1	1			1	
	Food Provisioning				1			1	
	Green Open Space: general	1	1	1				1	
	Habitat				1		0	1	
	Noise Reduction								0
	Pollination							1	
	Recreation/Tourism	1			1		1	1	
	Riparian or wetlands: general	1	1	1				1	
	Species Biodiversity								
	Storm Water Retention / management	1		1	1	1		1	
	Surface Contaminant Mitigation			0	0				
	Urban Heat Island Effect mitigation			1					0
	Violations/Compliance								
	Water Filtration / quality			0	1	1		1	
Resiliency	Data and modeling; knowledge and decision-making capability			0					
	Displacement and/or Relocation			0	0		1		0
	Economic Loss of Function	1	1		0/1			1	
	Emergency Response Services			0	0				
	Essential Facility and Critical Infrastructure Service Loss	1		0/1	0/1		1	0	
	Fatalities; injuries; human suffering	1	1		0				0
	Hazard reduction	1		1	1				
	Intrinsic value			1					
	Property Damage Reduction; property buyout		1	1	1/0		1	1	1
	Property Value due to risk reduction	1			1		1	1	
	Public education and stewardship		0	0					
	Public infrastructure O&M costs	1					1		
	Resilience plans, approaches, ordinances, guidelines								

Category	Benefit	Montana	Moore, O	New Jers	New Orle	New York	New York	Oregon
Community Development	Access to Education, Health, Food, and/or Social Services							0
	Benefits to LMI persons and/or Households	1	0		0	0	0	0
	Community identity and social cohesion		0			0		
	Equal access to resilient community assets				0			
	Historic and cultural amenity preservation							
	Housing supply, affordability, and/or availability	1		0		1	0/1	
	Living Conditions and Environment							
	Medical Costs / Physical & Mental Health	1	0	1	0	1	1	0
	Pressure on Social Services						0	
	Recreational value (other than bc env services)		0	1	1	1		
	Safety, Crime and Violence							
	Traffic & reduced vehicle use							1
Economic Revitalization	Alternative/Renewable Energy		0					
	Insurance Cost & coverage			1				
	Job Creation; Business support					0	0/1	
	Property Value independent of other benefits				1	0		
	Development or redevelopment		0			1		0
	Tourism; Effects on Local/Regional Economy		0	1		0/1	0	0
	Workforce benefits				1	1	0/1	
Environmental	Aesthetic Value				1		1	
	Air Quality						1	
	Biological Control							
	Climate Regulation		0		1	0	1	0
	Energy and/or Water Consumption; Wastewater production		0/1		0	0/1	1	0
	Erosion Control	1						
	Flood Hazard Reduction	1				1		
	Food Provisioning							
	Green Open Space: general	1						
	Habitat					0		
	Noise Reduction							
	Pollination							
	Recreation/Tourism	1			1	0	1	
	Riparian or wetlands: general	1		1		1	1	
	Species Biodiversity							
	Storm Water Retention / management	1			1	0	1	
	Surface Contaminant Mitigation							
	Urban Heat Island Effect mitigation				0		0	
	Violations/Compliance						1	
	Water Filtration / quality		0		1	0	1	
Resiliency	Data and modeling; knowledge and decision-making capability					0		
	Displacement and/or Relocation					1	1	
	Economic Loss of Function	1	1	1		0/1	0/1	1
	Emergency Response Services					0/1	0	
	Essential Facility and Critical Infrastructure Service Loss	1	0	1		1	1	1
	Fatalities; injuries; human suffering		1	1		0/1	1	0
	Hazard reduction				1	1		0
	Intrinsic value							
	Property Damage Reduction; property buyout	1	1	1	1	0/1	1	
	Property Value due to risk reduction		0	1			1	
	Public education and stewardship		0		1	0	0	
	Public infrastructure O&M costs	1			1	0		
	Resilience plans, approaches, ordinances, guidelines					0	0	

Category	Benefit	Shelby, TN	Springfield, MA	Tennesse	Texas	West Virginia
Community Development	Access to Education, Health, Food, and/or Social Services			0		
	Benefits to LMI persons and/or Households	0			0	
	Community identity and social cohesion	0		0	0	
	Equal access to resilient community assets	0				
	Historic and cultural amenity preservation			0	0	
	Housing supply, affordability, and/or availability				0	
	Living Conditions and Environment	0		0	0	
	Medical Costs / Physical & Mental Health	0/1	0/1	0	0	1
	Pressure on Social Services		1			
	Recreational value (other than bc env services)	0		0/1		
	Safety, Crime and Violence	0				
	Traffic & reduced vehicle use	1				
Economic Revitalization	Alternative/Renewable Energy	0	1	1		
	Insurance Cost & coverage					0
	Job Creation; Business support	0	0	1		1
	Property Value independent of other benefits	0	1			
	Development or redevelopment	0		0		0
	Tourism; Effects on Local/Regional Economy	0/1		0/1	0	
	Workforce benefits	0	0/1			
Environmental	Aesthetic Value					
	Air Quality	1				
	Biological Control					
	Climate Regulation	1	1	1	1	
	Energy and/or Water Consumption; Wastewater production	0	0/1	1	0	
	Erosion Control					
	Flood Hazard Reduction		1	0		
	Food Provisioning					
	Green Open Space: general	1		1		
	Habitat	1			0	
	Noise Reduction	0			0	
	Pollination					
	Recreation/Tourism					
	Riparian or wetlands: general	1	1	1		
	Species Biodiversity	1		0	0	
	Storm Water Retention / management	1		0		
	Surface Contaminant Mitigation			0		
	Urban Heat Island Effect mitigation	0/1	0		0	
	Violations/Compliance			0		1
	Water Filtration / quality	0	0	0	0	0
Resiliency	Data and modeling; knowledge and decision-making capability	0		0		0
	Displacement and/or Relocation	1				
	Economic Loss of Function	1	1		0	
	Emergency Response Services		1	0/1	0	
	Essential Facility and Critical Infrastructure Service Loss	1		0/1	0	0
	Fatalities; injuries; human suffering	0		0	0/1	
	Hazard reduction		1	0		0
	Intrinsic value					
	Property Damage Reduction; property buyout	1	0/1	0	0/1	0/1
	Property Value due to risk reduction	0/1	0	0	0	0
	Public education and stewardship	0/1	0	0		
	Public infrastructure O&M costs			1		
	Resilience plans, approaches, ordinances, guidelines	0				0

Appendix 2: Declared Disasters & NDRC Eligibility

Table 8. NDRC Eligible Units of General Local Government Applicants. Source: HUD.

Unit of General Local Government	Event
Birmingham, AL	2011 Tornadoes
Jefferson County, AL	2011 Tornadoes
Tuscaloosa, AL	2011 Tornadoes
Chicago, IL	2013 Flooding
Cook County, IL	2013 Flooding
Du Page County, IL	2013 Flooding
Jefferson Parish, LA	2012 Hurricane Isaac
New Orleans, LA	2012 Hurricane Isaac
St. Tammany Parish, LA	2012 Hurricane Isaac
Springfield, MA	2011 Tornadoes
Joplin, MO	2011 Tornadoes
Minot, ND	2011 Flooding
New York City, NY	2012 Hurricane Sandy
Moore, OK	2013 Tornadoes
Dauphin County, PA	2011 Hurricane Irene/ Tropical Storm Lee
Luzerne County, PA	2011 Hurricane Irene/ Tropical Storm Lee
Shelby County, TN	2011 Severe Storms

Table 9. State, district and territory-level eligible applicants to the NDRC and associated disaster(s). Source: HUD.

State	Disaster Number	Declared Counties	Incident Type	Title
AK	1992	3	Flood	ICE JAM AND FLOODING
AK	4050	5	Severe Storm(s)	SEVERE WINTER STORMS AND FLOODING
AK	4054	1	Severe Storm(s)	SEVERE STORM
AK	4094	5	Severe Storm(s)	SEVERE STORM, STRAIGHT-LINE WINDS, FL
AK	4122	5	Flood	FLOODING
AK	4161	1	Flood	FLOODING
AK	4162	4	Severe Storm(s)	SEVERE STORMS, STRAIGHT-LINE WINDS, A
AL	1971	67	Severe Storm(s)	SEVERE STORMS, TORNADOES, STRAIGHT-LI
AL	4052	3	Severe Storm(s)	SEVERE STORMS, TORNADOES, STRAIGHT-LI
AL	4082	8	Hurricane	HURRICANE ISAAC
AR	1975	60	Severe Storm(s)	SEVERE STORMS, TORNADOES, AND ASSOCIA
AR	4000	3	Severe Storm(s)	SEVERE STORMS, TORNADOES, AND FLOODIN
AR	4100	8	Severe Ice Storm	SEVERE WINTER STORM
AR	4124	11	Severe Storm(s)	SEVERE STORMS, TORNADOES, AND FLOODIN

State	Disaster Number	Declared Counties	Incident Type	Title
AR	4143	6	Severe Storm(s)	SEVERE STORMS AND FLOODING
AR	4160	14	Severe Ice Storm	SEVERE WINTER STORM
AZ	4104	1	Freezing	SEVERE FREEZE
CA	1952	10	Flood	SEVERE WINTER STORMS, FLOODING, AND D
CA	1968	3	Tsunami	TSUNAMI WAVES
CA	4142	1	Fire	WILDFIRE
CA	4158	1	Fire	RIM FIRE
CO	4145	18	Flood	SEVERE STORMS, FLOODING, LANDSLIDES,
CO	4067	3	Fire	HIGH PARK AND WALDO CANYON WILDFIRES
CO	4133	1	Fire	ROYAL GORGE FIRE
CO	4134	1	Fire	BLACK FOREST WILDFIRE
CT	4023	8	Hurricane	TROPICAL STORM IRENE
CT	4087	8	Hurricane	HURRICANE SANDY
CT	1958	8	Snow	SNOWSTORM
CT	4046	7	Severe Storm(s)	SEVERE STORM
CT	4106	9	Severe Storm(s)	SEVERE WINTER STORM AND SNOWSTORM
DC	4036	1	Hurricane	HURRICANE IRENE
DC	4044	1	Earthquake	EARTHQUAKE
DC	4073	1	Severe Storm(s)	SEVERE STORMS
DC	4096	1	Hurricane	HURRICANE SANDY
DE	4037	2	Hurricane	HURRICANE IRENE
DE	4090	3	Hurricane	HURRICANE SANDY
FL	4068	34	Severe Storm(s)	TROPICAL STORM DEBBY
FL	4084	12	Hurricane	HURRICANE ISAAC
FL	4138	4	Severe Storm(s)	SEVERE STORMS AND FLOODING
GA	1973	26	Severe Storm(s)	SEVERE STORMS, TORNADOES, STRAIGHT-LI
HI	1967	3	Tsunami	TSUNAMI WAVES
HI	4062	2	Severe Storm(s)	SEVERE STORMS, FLOODING, AND LANDSLID
IA	1977	6	Severe Storm(s)	SEVERE STORMS, TORNADOES, AND STRAIGH
IA	1998	6	Flood	FLOODING
IA	4016	6	Severe Storm(s)	SEVERE STORMS, STRAIGHT-LINE WINDS, A
IA	4018	2	Severe Storm(s)	SEVERE STORMS AND FLOODING
IA	4114	5	Severe Storm(s)	SEVERE WINTER STORM
IA	4119	20	Flood	SEVERE STORMS, STRAIGHT-LINE WINDS, A
IA	4126	49	Severe Storm(s)	SEVERE STORMS, TORNADOES, AND FLOODIN
IA	4135	12	Severe Storm(s)	SEVERE STORMS, TORNADOES, AND FLOODIN
ID	1987	6	Flood	FLOODING, LANDSLIDES, AND MUDSLIDES
IL	4116	47	Flood	SEVERE STORMS, STRAIGHT-LINE WINDS, A
IL	1960	65	Snow	SEVERE WINTER STORM AND SNOWSTORM

State	Disaster Number	Declared Counties	Incident Type	Title
IL	1991	21	Severe Storm(s)	SEVERE STORMS AND FLOODING
IL	4157	15	Tornado	SEVERE STORMS, STRAIGHT-LINE WINDS, A
IN	1997	36	Severe Storm(s)	SEVERE STORMS, TORNADOES, STRAIGHT-LI
IN	4058	6	Severe Storm(s)	SEVERE STORMS, STRAIGHT-LINE WINDS, A
KS	4010	25	Severe Storm(s)	SEVERE STORMS, STRAIGHT-LINE WINDS, T
KS	4035	4	Flood	FLOODING
KS	4063	14	Severe Storm(s)	SEVERE STORMS, TORNADOES, STRAIGHT-LI
KS	4112	23	Snow	SNOWSTORM
KS	4150	46	Severe Storm(s)	SEVERE STORMS, STRAIGHT-LINE WINDS, T
KY	1976	79	Severe Storm(s)	SEVERE STORMS, TORNADOES, AND FLOODIN
KY	4008	7	Severe Storm(s)	SEVERE STORMS, TORNADOES, AND FLOODIN
KY	4057	23	Severe Storm(s)	SEVERE STORMS, TORNADOES, STRAIGHT-LI
LA	4080	55	Hurricane	HURRICANE ISAAC
LA	4015	22	Flood	FLOODING
LA	4041	8	Coastal Storm	TROPICAL STORM LEE
LA	4102	11	Severe Storm(s)	SEVERE STORMS AND FLOODING
MA	1994	2	Tornado	SEVERE STORMS AND TORNADOES
MA	1959	7	Snow	SEVERE WINTER STORM AND SNOWSTORM
MA	4028	9	Hurricane	TROPICAL STORM IRENE
MA	4051	6	Severe Storm(s)	SEVERE STORM AND SNOWSTORM
MA	4097	6	Hurricane	HURRICANE SANDY
MA	4110	14	Severe Storm(s)	SEVERE WINTER STORM, SNOWSTORM, AND F
MD	4091	24	Hurricane	HURRICANE SANDY
MD	4034	15	Hurricane	HURRICANE IRENE
MD	4038	7	Flood	REMNANTS OF TROPICAL STORM LEE
MD	4075	6	Severe Storm(s)	SEVERE STORMS AND STRAIGHT-LINE WINDS
ME	4032	4	Hurricane	TROPICAL STORM IRENE
ME	4108	6	Severe Storm(s)	SEVERE WINTER STORM, SNOWSTORM, AND F
MI	4121	16	Flood	FLOODING
MN	1982	34	Flood	SEVERE STORMS AND FLOODING
MN	1990	2	Severe Storm(s)	SEVERE STORMS AND TORNADOES
MN	4009	16	Severe Storm(s)	SEVERE STORMS, FLOODING, AND TORNADOE
MN	4069	18	Severe Storm(s)	SEVERE STORMS AND FLOODING
MN	4113	5	Severe Storm(s)	SEVERE WINTER STORM
MN	4131	18	Severe Storm(s)	SEVERE STORMS, STRAIGHT-LINE WINDS, A
MO	1980	41	Severe Storm(s)	SEVERE STORMS, TORNADOES, AND FLOODIN
MO	1961	62	Severe Storm(s)	SEVERE WINTER STORM AND SNOWSTORM
MO	4012	11	Flood	FLOODING
MO	4130	28	Severe Storm(s)	SEVERE STORMS, STRAIGHT-LINE WINDS, T

State	Disaster Number	Declared Counties	Incident Type	Title
MO	4144	18	Severe Storm(s)	SEVERE STORMS, STRAIGHT-LINE WINDS AN
MS	1972	40	Severe Storm(s)	SEVERE STORMS, TORNADOES, STRAIGHT-LI
MS	1983	14	Flood	FLOODING
MS	4081	49	Hurricane	HURRICANE ISAAC
MS	4101	7	Severe Storm(s)	SEVERE STORMS, TORNADOES, AND FLOODIN
MT	1996	55	Severe Storm(s)	SEVERE STORMS AND FLOODING
MT	4074	3	Fire	WILDFIRE
MT	4127	15	Flood	FLOODING
NC	4019	38	Hurricane	HURRICANE IRENE
NC	1969	20	Severe Storm(s)	SEVERE STORMS, TORNADOES, AND FLOODIN
NC	4103	1	Mud/Landslide	SEVERE STORMS, FLOODING, LANDSLIDES,
NC	4146	14	Flood	SEVERE STORMS, FLOODING, LANDSLIDES,
NC	4153	6	Flood	SEVERE STORMS, FLOODING, LANDSLIDES,
ND	1981	48	Flood	FLOODING
ND	1986	9	Severe Storm(s)	SEVERE WINTER STORM
ND	4118	17	Flood	FLOODING
ND	4123	1	Flood	SEVERE STORMS AND FLOODING
ND	4128	21	Severe Storm(s)	SEVERE STORMS AND FLOODING
ND	4154	7	Severe Storm(s)	SEVERE WINTER STORM
NE	4013	17	Flood	FLOODING
NE	4014	12	Severe Storm(s)	SEVERE STORMS, TORNADOES, STRAIGHT LI
NE	4156	10	Severe Storm(s)	SEVERE STORMS, WINTER STORMS, TORNADO
NH	4006	2	Flood	SEVERE STORMS AND FLOODING
NH	4026	7	Hurricane	TROPICAL STORM IRENE
NH	4049	2	Severe Storm(s)	SEVERE STORM AND SNOWSTORM
NH	4065	1	Severe Storm(s)	SEVERE STORM AND FLOODING
NH	4095	6	Hurricane	HURRICANE SANDY
NH	4105	8	Severe Storm(s)	SEVERE WINTER STORM AND SNOWSTORM
NH	4139	3	Severe Storm(s)	SEVERE STORMS, TORNADOES, AND FLOODIN
NJ	4021	21	Hurricane	HURRICANE IRENE
NJ	4086	21	Hurricane	HURRICANE SANDY
NJ	4033	3	Severe Storm(s)	SEVERE STORMS AND FLOODING
NJ	4039	5	Severe Storm(s)	REMNANTS OF TROPICAL STORM LEE
NJ	4048	11	Severe Storm(s)	SEVERE STORM
NJ	4070	3	Severe Storm(s)	SEVERE STORMS AND STRAIGHT-LINE WINDS
NM	1962	15	Severe Storm(s)	SEVERE WINTER STORM AND EXTREME COLD
NM	4047	6	Flood	FLOODING
NM	4079	5	Flood	FLOODING
NM	4147	1	Severe Storm(s)	SEVERE STORMS AND FLOODING

State	Disaster Number	Declared Counties	Incident Type	Title
NM	4148	11	Severe Storm(s)	SEVERE STORMS AND FLOODING
NM	4151	1	Severe Storm(s)	SEVERE STORMS AND FLOODING
NM	4152	26	Flood	SEVERE STORMS, FLOODING, AND MUDSLIDE
NY	4020	32	Hurricane	HURRICANE IRENE
NY	4031	15	Severe Storm(s)	REMNANTS OF TROPICAL STORM LEE
NY	4085	14	Hurricane	HURRICANE SANDY
NY	1993	23	Flood	SEVERE STORMS, FLOODING, TORNADOES, A
NY	4111	1	Severe Storm(s)	SEVERE WINTER STORM AND SNOWSTORM
NY	4129	16	Flood	SEVERE STORMS AND FLOODING
OH	4002	21	Severe Storm(s)	SEVERE STORMS AND FLOODING
OH	4077	39	Severe Storm(s)	SEVERE STORMS AND STRAIGHT-LINE WINDS
OH	4098	2	Hurricane	SEVERE STORMS AND FLOODING DUE TO THE
OK	4078	2	Fire	FREEDOM AND NOBLE WILDFIRES
OK	4117	21	Tornado	SEVERE STORMS, TORNADOES, AND FLOODIN
OK	1970	2	Severe Storm(s)	SEVERE STORMS, TORNADOES, AND STRAIGH
OK	1985	16	Severe Storm(s)	SEVERE WINTER STORM AND SNOWSTORM
OK	1988	10	Severe Storm(s)	SEVERE STORMS AND FLOODING
OK	1989	15	Severe Storm(s)	SEVERE STORMS, TORNADOES, STRAIGHT-LI
OK	4064	5	Severe Storm(s)	SEVERE STORMS, TORNADOES, STRAIGHT-LI
OK	4109	17	Severe Storm(s)	SEVERE WINTER STORM AND SNOWSTORM
OK	4164	4	Severe Storm(s)	SEVERE WINTER STORM
OR	1956	6	Severe Storm(s)	SEVERE WINTER STORM, FLOODING, MUDSLI
OR	1964	3	Tsunami	TSUNAMI WAVE SURGE
OR	4055	12	Flood	SEVERE WINTER STORM, FLOODING, LANDSL
PA	4025	14	Hurricane	HURRICANE IRENE
PA	4030	34	Flood	TROPICAL STORM LEE
PA	4003	5	Severe Storm(s)	SEVERE STORMS AND FLOODING
PA	4099	18	Hurricane	HURRICANE SANDY
PA	4149	11	Severe Storm(s)	SEVERE STORMS, TORNADOES, AND FLOODIN
PR	4004	13	Severe Storm(s)	SEVERE STORMS, FLOODING, MUDSLIDES, A
PR	4017	56	Hurricane	HURRICANE IRENE
PR	4040	3	Hurricane	TROPICAL STORM MARIA
RI	4089	4	Hurricane	HURRICANE SANDY
RI	4027	6	Hurricane	TROPICAL STORM IRENE
RI	4107	5	Severe Storm(s)	SEVERE WINTER STORM AND SNOWSTORM
SD	1984	40	Flood	FLOODING
SD	4115	8	Severe Storm(s)	SEVERE WINTER STORM AND SNOWSTORM
SD	4125	6	Severe Storm(s)	SEVERE STORMS, TORNADO, AND FLOODING
SD	4137	8	Severe Storm(s)	SEVERE STORMS, TORNADOES, AND FLOODIN

State	Disaster Number	Declared Counties	Incident Type	Title
SD	4155	16	Severe Storm(s)	SEVERE WINTER STORM, SNOWSTORM, AND F
TN	1979	18	Severe Storm(s)	SEVERE STORMS, STRAIGHT-LINE WINDS, T
TN	1965	13	Severe Storm(s)	SEVERE STORMS, TORNADOES, AND FLOODIN
TN	1974	52	Severe Storm(s)	SEVERE STORMS, TORNADOES, STRAIGHT-LI
TN	1978	9	Severe Storm(s)	SEVERE STORMS, FLOODING, TORNADOES, A
TN	4005	7	Severe Storm(s)	SEVERE STORMS, STRAIGHT-LINE WINDS, T
TN	4060	10	Severe Storm(s)	SEVERE STORMS, TORNADOES, STRAIGHT-LI
TX	4029	65	Fire	WILDFIRES
TX	1999	122	Fire	WILDFIRES
TX	4136	1	Other	EXPLOSION
TX	4159	4	Severe Storm(s)	SEVERE STORMS AND FLOODING
UT	4011	19	Flood	FLOODING
UT	4053	1	Other	SEVERE STORM
UT	4088	1	Flood	SEVERE STORM AND FLOODING
VA	4024	48	Hurricane	HURRICANE IRENE
VA	4042	10	Earthquake	EARTHQUAKE
VA	4045	8	Severe Storm(s)	THE REMNANTS OF TROPICAL STORM LEE
VA	4072	69	Severe Storm(s)	SEVERE STORMS AND STRAIGHT-LINE WINDS
VA	4092	29	Hurricane	HURRICANE SANDY
VT	4001	4	Severe Storm(s)	SEVERE STORMS AND FLOODING
VT	4022	14	Hurricane	TROPICAL STORM IRENE
VT	1995	8	Severe Storm(s)	SEVERE STORMS AND FLOODING
VT	4043	3	Severe Storm(s)	SEVERE STORMS AND FLOODING
VT	4066	3	Severe Storm(s)	SEVERE STORM, TORNADO, AND FLOODING
VT	4120	3	Flood	SEVERE STORMS AND FLOODING
VT	4140	7	Flood	SEVERE STORMS AND FLOODING
VT	4163	7	Severe Ice Storm	SEVERE WINTER STORMS
WA	1963	7	Severe Storm(s)	SEVERE WINTER STORM, FLOODING, LANDSL
WA	4056	11	Severe Storm(s)	SEVERE WINTER STORM, FLOODING, LANDSL
WA	4083	3	Severe Storm(s)	SEVERE STORM, STRAIGHT-LINE WINDS, AN
WI	1966	11	Snow	SEVERE WINTER STORM AND SNOWSTORM
WI	4076	4	Severe Storm(s)	SEVERE STORMS AND FLOODING
WI	4141	8	Severe Storm(s)	SEVERE STORMS, FLOODING, AND MUDSLIDE
WV	4059	11	Severe Storm(s)	SEVERE STORMS, TORNADOES, FLOODING, M
WV	4061	3	Severe Storm(s)	SEVERE STORMS, FLOODING, MUDSLIDES, A
WV	4071	47	Severe Storm(s)	SEVERE STORMS AND STRAIGHT-LINE WINDS
WV	4093	18	Hurricane	HURRICANE SANDY
WV	4132	2	Flood	SEVERE STORMS AND FLOODING
WY	4007	16	Severe Storm(s)	SEVERE STORMS, FLOODING, AND LANDSLID

Appendix 3: CDBG-DR Allocated Funds

Table 10. CDBG-DR funds allocated as of June 2014 from leftover funds outside of the NDRC. Source: HUD NDRC Phase 2 NOFA Appendix B.

State	Grantee	Total "Sandy Supplemental"	Total All CDBG DR-Grants 2011, 2012, 2013
AL	AL State	$49,157,000	$73,854,966
AL	TUSCALOOSA	$43,932,000	$60,566,702
AL	BIRMINGHAM	$17,497,000	$23,883,326
AL	JEFFERSON COUNTY	$9,142,000	$16,989,084
CO	CO State	$262,100,000	$262,100,000
CT	Connecticut	$159,279,000	$159,279,000
IL	Chicago, IL	$52,000,000	$52,000,000
IL	Cook County, IL	$68,800,000	$68,800,000
IL	Du Page County, IL	$25,900,000	$25,900,000
IL	Illinois State	$10,400,000	$10,400,000
LA	LA State	$66,398,000	$66,398,000
LA	JEFFERSON PARISH	$16,453,000	$16,453,000
LA	NEW ORLEANS	$15,031,000	$15,031,000
LA	ST. TAMMANY PARISH	$8,896,000	$8,896,000
MA	MA State	$7,210,000	$7,210,000
MA	SPRINGFIELD	$21,896,000	$21,896,000
MD	Maryland	$28,640,000	$28,640,000
MO	MO State	$11,844,000	$20,563,059
MO	JOPLIN	$113,276,000	$158,542,709
ND	ND State	$6,576,000	$18,358,684
ND	MINOT	$35,056,000	$102,631,964
NJ	New Jersey	$4,174,429,000	$4,190,027,506
NY	New York City	$4,213,876,000	$4,213,876,000
NY	New York	$4,416,882,000	$4,488,536,116
NY	Orange County	$0	$11,422,029
NY	Union Township	$0	$10,137,818
OK	Moore, OK	$52,200,000	$52,200,000
OK	Oklahoma State	$93,700,000	$93,700,000
PA	PA State	$29,986,000	$57,128,501
PA	LUZERNE COUNTY	$9,763,000	$25,501,806
PA	DAUPHIN COUNTY	$7,632,000	$14,047,833
RI	Rhode Island	$19,911,000	$19,911,000
TN	TN State	$13,810,000	$13,810,000
TN	SHELBY COUNTY	$7,464,000	$7,464,000
TX	TX State	$5,061,000	$36,380,686
VT	VT State	$17,932,000	$39,592,211
	TOTAL	**$14,111,129,000**	**$14,511,129,000**

Appendix 4: Interview Guide

- Please describe your role as the [Title @ office] and your involvement with the NDRC.
- Please describe the process of compiling the BCA during Phase 2 of the NDRC in [State/County/City].
    - What was the convening style – weekly one-hour meetings? Full-day conference?
    - Who was in attendance / Who was involved in identifying and measuring costs and benefits?
- Did you hire outside consultants to assist with the BCA? If yes, who were they and how did you choose them?
- At what stage of the NDRC application process did you involve outside partners? What kind of information was used to recruit their participation/involvement?
- In your opinion, what are the greatest opportunities to build leverage?
    - Through the NDRC application process?
    - Through the BCA?
- In your opinion, what are the biggest challenges to build leverage?
    - Through the NDRC application process?
    - Through the BCA?
- Have any new partnerships been built from the NDRC application process? Through the BCA development process?
- Of the expected benefits listed in the proposed project, has any follow-up or monitoring been done to measure the benefit? If so, for which benefits?
- Which benefits are most difficult to track/measure?