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Fact Sheet

Nature as Resilient Infrastructure: An Overview of Nature-Based Solutions

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Our nation's "gray," or hard, manmade infrastructure is in need of repair and upgrading due to age, deferred maintenance, and the toll of more intense and frequent extreme weather events resulting from climate change. The American Society of Civil Engineers (ASCE)—which has graded the condition of the country's public infrastructure as a D+ for nearly a decade—estimates direct, cumulative gray infrastructure repair needs at $4.6 trillion through 2025, with an estimated funding gap of $2.1 trillion.[1] Infrastructure has long been an area of bipartisan agreement, and the 116th Congress and White House continue to allude to a possible infrastructure bill or package. As discussions take shape on the future of the country's infrastructure, it is important to ensure projects are cost-effective, sustainable, and resilient to the impacts of climate change.

Although infrastructure is often thought of as manmade structures and buildings, it can also include natural systems, such as wetlands, and systems that emulate nature, such as green roofs. As policymakers fund improvements to the nation's infrastructure, natural systems and solutions, referred to as nature-based solutions, should also be considered critical infrastructure. Currently, the 116th Congress is incorporating some of these nature-based solutions into a variety of legislation, including the *Living Shorelines Act of 2019*, the *Climate Stewardship Act*, and the *American Transportation Act of 2019*.

Extending the definition of infrastructure to include natural systems provides an opportunity to work with nature and employ nature-based solutions to create sustainable, climate-resilient solutions to the country's infrastructure needs. These nature-based solutions are often higher-quality, lower-cost, more resilient, and more beneficial to society than maintaining, repairing, or replacing gray infrastructure.[2,3,4,5,6] Therefore, nature-based solutions can help the United States meet the infrastructure investment gap in a cost-effective manner, while producing substantial social, economic, and environmental co-benefits.[4,7] Combining gray infrastructure and nature-based solutions, often referred to as a hybrid approach, can also provide a favorable avenue for rethinking and remodeling our nation's infrastructure.

By surveying definitions of nature-based solutions and providing specific examples of solutions and projects, this fact sheet contributes to the national conversation about two critical policy issues: **how to fix America's crumbling infrastructure** and **how to make communities more resilient to climate impacts**.

Defining Nature-Based Solutions

Nature-Based Solutions

Nature-based solutions are intended to address infrastructure needs, protect from climate impacts, and act as hazard mitigation tools (also referred to as 'pre-disaster mitigation'). However, there is no universal definition for nature-based solutions; organizations define it in different ways and employ different terminologies.[8]

Definitions of nature-based solutions include:

- The **International Union for Conservation of Nature** (IUCN), the **World Bank Group**, and the **World Resources Institute** (WRI) define nature-based solutions as "actions to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits."[2,4]
- **The Nature Conservancy** states nature-based solutions are "project solutions that are motivated and supported by nature and that may also offer environmental, economic, and social benefits, while increasing resilience. Nature-based solutions include both green and natural infrastructure."[8]
- **The National Oceanic and Atmospheric Administration** (NOAA) Office for Coastal Management employs a similar term to nature-based solutions, Ecosystem-based Management, defined as "an integrated management approach that recognizes the full array of interactions within an ecosystem … an approach that works across sectors to manage species and habitats, economic activities, conflicting uses, and the sustainability of resources."[8]
- The **US Army Corps of Engineers** uses yet another similar term, Engineering with Nature, or "the intentional alignment of natural and engineering processes to efficiently and sustainably deliver economic, environmental, and social benefits through collaboration."[9]

Green and Natural Infrastructure

The terms green infrastructure and natural infrastructure are similar to nature-based solutions. They are sometimes used interchangeably with nature-based solutions, and other times as more specific concepts that fall under the larger nature-based solutions umbrella. They also do not have universal definitions.

- The **IUCN** defines *green infrastructure* as incorporating "green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. A green infrastructure approach considers conservation values and actions related to land development, growth management, and built infrastructure planning." They define *natural infrastructure* as "restoring structure, function, and composition of ecosystems to deliver ecosystem services."[10]
- **The World Bank Group** and **WRI** use these terms interchangeably, defining a green/natural infrastructure project as an initiative that "intentionally and strategically preserves, enhances, or restores elements of a natural system … and combines them with gray infrastructure to produce more resilient and lower-cost services."[4]
- The **American Society of Landscape Architects** defines the term *green infrastructure* as humans harnessing nature for use as an infrastructural system. This can be done at a landscape or site-specific scale, and includes both natural system restoration/protection and built projects that emulate nature.[11,12]

EESI's Definitions

This fact sheet's terminology is informed by this set of definitions and closely follows The Nature Conservancy's definitions of nature-based solutions, green infrastructure, and natural infrastructure. **EESI uses nature-based solutions as an umbrella term with green infrastructure and natural infrastructure being sub-categories of nature-based solutions.**

- **Nature-based solutions** – Restoring and/or emulating nature in order to increase human, ecosystem, and infrastructure resilience to climate impacts. These solutions often result in environmental, economic, and social co-benefits, including carbon sequestration—a key tool in mitigating greenhouse gas emissions. Nature-based solutions includes both green and natural infrastructure.[8]
    - **Green infrastructure** – Projects that combine gray infrastructure with nature-based solutions to create hybrid systems that improve resilience to climate impacts, while also often resulting in environmental, economic, and social co-benefits. Generally, green infrastructure is a built or engineered solution such as a green roof or bioswale.[8]
    - **Natural infrastructure** – Projects that use existing or rebuilt natural landscapes (i.e., forests, floodplains, and wetlands) to increase resilience to climate impacts, often resulting in environmental, economic, and social co-benefits.[8]

Developing climate-resilient infrastructure is of utmost importance as climate change impacts—such as increasing temperatures, severe weather events, and sea level rise—become more common. Nature-based solutions are beneficial infrastructure options because they have a smaller carbon footprint than gray infrastructure and often sequester carbon. This fact sheet focuses on nature-based solutions that not only address the challenge of outdated gray infrastructure, but also increase an area's resilience to climate impacts and contribute to climate mitigation efforts. This dual effect of nature-based solutions is particularly important because, without significant reductions in greenhouse gas emissions, climate impacts will become worse, causing more severe impacts on the nation's infrastructure.[13]

Nature-Based Solutions for Coastal Storms, Sea Level Rise, and Erosion

Coastal communities are experiencing the effects of climate change, including sea level rise, more intense storms, flooding, and erosion. Coastal flooding has more than doubled in the past 30 years, according to the *Climate Science Special Report* by the U.S. Global Change Research Program.[14] Additionally, due to sea level rise, high tides are becoming higher and higher, and the highest tides—king tides, which usually occur seasonally—are projected to become daily high tides, leading to even further flooding.[15] On top of this, gray infrastructure built to "control" flooding, especially in the face of extreme weather, is increasingly failing to do its job.[14,16] Hurricanes Michael (2018), Maria (2017), Irma (2017), and Harvey (2017) created a total of $290 billion in damages, forced communities to evacuate, and caused more than 3,000 associated fatalities across the United States and Caribbean countries.[17,18,19,20]

Climate change impacts require a re-evaluation of infrastructure solutions. Studies suggest coastal nature-based solutions can mitigate flood and storm damage more effectively than gray infrastructure alone, and are more resilient.[3,6,21,22,23,24] For these reasons, coastal states are investing in **natural infrastructure solutions**:

- **The restoration of wetlands, mangroves, marshes, and oyster reefs, and the installation of living shorelines** (plants and natural elements designed to stabilize and protect coastlines) help reduce wave impacts during storms. Fifteen feet of **marsh** can "absorb up to 50 percent of incoming wave energy," and 330 feet of **mangrove trees** "can reduce wave height by 66 percent."[3] By contrast, gray infrastructure redirects, rather than dissipates, wave energy.[3,6] Furthermore, waves can overtop jetties, bulkheads, levees, and seawalls, so flood protection is only provided to a certain peak wave height.[25]
- **Marshes** collect sand and sediments from the water and can grow in elevation as sea levels rise, while gray infrastructures cannot adapt and must be updated or replaced to deal with higher water levels.[21]
- A study conducted by the University of North Carolina Chapel Hill after Hurricane Matthew (2016) found **living shorelines** prevented erosion just as well as bulkheads (retaining walls meant to prevent flooding), but required no repairs after the hurricane, whereas 75 percent of the bulkheads needed repairs.[24] After Hurricane Florence (2018) hit, seawalls experienced "significant erosion and damage," while living shorelines, such as the Beaufort living shoreline composed of oyster reef and marsh, fared much better.[23]

These natural infrastructure solutions are generally cost-effective, depending on the specific site.[4] For many locations along the Gulf of Mexico, **wetland** and **reef restoration** have been found to save $7 in "flood reduction benefits" for every $1 spent on restoration, and it is estimated that nature-based solutions could help "avert more than 45 percent of the climate risk over a 20-year period, saving the region more than $50 billion in flood damages."[6] Across the United States, coastal wetlands are estimated to provide $23.2 billion in storm protection annually.[6] One case study determined that, with regards to Hurricane Sandy (2012), coastal wetlands prevented an estimated $625 million in property damages.[22] Annually, in the Northeastern United States, coastal wetlands provide a 16 percent reduction in flood damages.[22] Another study found that combining gray infrastructure with nature-based solutions was the most effective method for mitigating flooding while providing the greatest co-benefits, saving $225 million in damages for a 1-in-100 year storm event at Howard Beach, Queens, New York.[26] Additionally, initial costs for nature-based solutions are often cheaper than for gray infrastructure alternatives. As of June 2019, living shorelines, which last longer and do not require as many or as intensive repairs, on average cost $361/linear foot, which is a third of the $1,022/linear foot cost for concrete bulkheads.[23,27]

Co-Benefits

Coastal nature-based solutions provide a slew of co-benefits, such as carbon sequestration, water quality improvement, erosion reduction, habitat provision, and support for recreation and tourism industries.[28] For example, oyster reefs are estimated to provide services of almost $40,000/acre annually, including water quality improvement and erosion reduction.[6] Each year, 1 square mile of salt marshes stores carbon equal to 76,000 gallons of gasoline.[21]

Current Projects

- Along **Alabama's Gulf Coast,** The Nature Conservancy and its partners have, since 2005, worked with local communities to install more than nine miles of oyster reefs and marshes, at a cost of approximately $28 million. This project aims to limit erosion, compensate for sea level rise, and manage wave energy, while also providing habitat for native species. Continued monitoring reports have shown "significant progress."[29]
- The U.S. Army Corps of Engineers executed the Oyster Reef Shoreline Stabilization Project in **Tampa, Florida**, from 2004 to 2012. The Army Corps built oyster reefs to reduce wave energy and accumulate sediment (which helps systems adjust to sea level rise), and restored previous salt marsh and mangrove systems along the coast, creating habitat.[30]
- The San Francisco Bay Living Shorelines Project established native eelgrass and oyster beds to protect and stabilize the coast. Started in 2011, the $2.1 million project reduces wave energy by 30-50 percent, has accumulated between 15-24 cm of sediment, and creates habitat for species such as fish, birds, and crustaceans.[31]

Nature-Based Solutions for Inland Flooding

As a result of increased temperatures and rainfall due to climate change—combined with a reduction of natural landscapes and an increase of impermeable surfaces due to development—many regions are experiencing more frequent and intense flooding.[14,32,33] From rural areas and farmlands to urban centers, flooding spreads pollution, creates public health concerns, damages infrastructure, kills crops, damages farms, affects individuals' livelihoods, and causes more than 100 fatalities in the United States each year.[14,34] Additionally, floods are expensive. From 1998 to 2014, the Federal Emergency Management Agency (FEMA) provided $48.6 billion in grants for infrastructure repairs, and between 2007 and 2017, the National Flood Insurance Program (NFIP) on average paid $2.9 billion annually in flood-related losses.[14] These damages come from riverine flooding and overflow from storm drainage systems (discussed in this section) and coastal flooding (discussed in the section above). Because floods are so costly and have so many negative impacts, it is deeply concerning that flooding is projected to increase and floodplains (areas that experience flooding) are estimated to expand 45 percent by 2100.[14]

While gray infrastructure exacerbates flooding in many cases, and is costly to update to handle increased water flow, nature-based solutions can help mitigate flooding from overflowing rivers and storm drainage systems in cost-effective ways.[5,33,35,36,37,38] According to the National Institute of Building Sciences, federal funding for riverine flood reduction can save $7 in avoided damages for every $1 invested.[33,38] While a comparable federal analysis does not exist for flooding from storm drainage systems, many cities have completed assessments estimating green infrastructure projects would be significantly cheaper in the long term than upgrading or building gray infrastructure.[5,37] In Los Angeles, a storm drainage system retrofit project is estimated to cost between $2.8 and $7.4 billion for green infrastructure, compared to approximately $44 billion for traditional gray infrastructure.[37] In Philadelphia, implementing a new green infrastructure plan would cost $1.2 billion over 25 years, whereas a comparable gray infrastructure plan would cost $6 billion.[5]

According to an EPA study of 20 watersheds that are projected to grow between 2020 and 2040 due to increased precipitation and development, using green infrastructure to mitigate flooding from storm drainage systems can save hundreds of millions of dollars.[36] However, the solutions a community employs depends on its specific location, existing infrastructure, and the type of flooding it faces—either riverine or from storm drainage systems—so all potential solutions should be evaluated in context before being implemented.

Green infrastructure solutions can often be used to mitigate both types of flooding, while natural infrastructure is generally more applicable to riverine flooding. Additionally, it is important to note that these strategies can be used by coastal communities to help mitigate flooding as well.

Green infrastructure solutions for flooding include:

- **Green Roofs** – Roofs covered in plants to make a living landscape. They collect 40 to 80 percent of precipitation which falls on the roof and release it slowly to reduce flooding. While on average they initially cost up to two times as much as traditional roofs, over time, they are more cost–effective, and can last two or three times as long as traditional roofs.[5,39]
- **Rain Gardens** – Gardens planted in shallow basins in yards and along streets or sidewalks to absorb street, sidewalk, and rooftop runoff. They are typically 30 percent more absorbent than a traditional lawn.[34]
- **Bioswales** – Long, deep channels of plants and grasses along roads and parking lots that absorb runoff and release water slowly.[5]
- **Urban Tree Canopies** – The intentional planting of trees throughout cities. Trees collect raindrops before they hit the ground, giving rain more time to evaporate instead of turning to runoff. Deciduous trees can collect up to 700 gallons/year, and evergreens up to 4,000 gallons/year.[5]
- **Permeable Pavements** – Pavements made of materials such as porous concrete that allow water to filter through and into the soil instead of turning into runoff. They can be up to 50 percent less expensive to install than traditional pavement and are generally cheaper to maintain.[5]

Natural infrastructure solutions for flooding include:

- **Protecting and/or restoring wetlands and marshes** – They can help absorb precipitation and reduce runoff. One acre of wetlands can store and filter up to 330,000 gallons of water.[33,37]
- **Protecting and/or restoring riparian buffers** – Vegetated or forested buffers along rivers or streams reduce the amount of water entering waterways. Natural systems can absorb up to 90 percent of the precipitation they receive.[5,33]

Co-benefits

By reducing runoff and increasing filtration, these green and natural infrastructure strategies help to minimize water pollution. This improves water quality, and can reduce water treatment costs by 25 percent or more.[5] Planting native plants can help reduce the usage of chemical fertilizers, further improving water quality. This provides public health benefits because people are less exposed to polluted water and drinking water contaminants.[5] Rain gardens, bioswales, permeable pavements, and natural infrastructures can help replenish groundwater supplies by absorbing and filtering water.[5,40] The solutions that involve plants/ecosystems sequester carbon, helping to mitigate climate change.[5] Additionally, many of these solutions also help reduce extreme heat, as discussed in the section below.

Current Projects

- In **Wisconsin**, The Conservation Fund's Greenseams program has protected over 3,600 acres of natural, flood-prone landscapes throughout Milwaukee and nearby counties, including watersheds and rural communities. The protected area, which is being restored to native wetlands, prairies, and forest habitats, can store 1.3 billion gallons of water to help lower river water levels and slow flows.[41,42]
- In communities throughout **Chicago** and the greater Illinois area, RainReady helps communities and homeowners retrofit their homes and yards to help minimize flooding. This includes providing funding for rain gardens and planting trees, amongst other nature-based solutions.[43]
- Green City, Clean Waters is a 25-year green infrastructure retrofit project in **Philadelphia** to reduce flooding and pollution from gray stormwater infrastructure. The project installs permeable pavement, green roofs, rain gardens, and other nature-based solutions. More than 1,000 of the 10,000 project acres have been "greened."[5,44]

Nature-Based Solutions for Extreme Heat

According to a 2019 report from the Union of Concerned Scientists, the frequency and severity of extreme heat is projected to grow over the coming decades as a result of climate change, bringing with it health and safety risks.[45] Already, extreme heat is the leading cause of weather-related deaths, claiming more than 600 lives annually.[45] Under a business-as-usual scenario, by 2050, 150 U.S. cities, compared to three cities at present, will experience 30+ days each year with a heat index above 105℉, leading to even more heat-related illnesses and deaths.[45] Even if greenhouse gas emissions are slowly reduced, by 2050, 80 cities will still have 30+ days each year with a heat index above 105℉.[45]

Gray infrastructure, and particularly roads, parking lots, and buildings, exacerbate extreme heat because they reduce moisture in the air and absorb more heat than vegetation does.[40] One way to locally adapt and help keep people and other species safe from extreme heat is to implement nature-based solutions that help lower temperatures in developed areas. Green infrastructure solutions that are useful in mitigating flooding—discussed in the above section—also can help mitigate heat. These solutions include:

- **Green Roofs** – They can be up to 30-40℉ cooler than typical roofs and reduce citywide temperatures by up to 5℉. They can reduce building air conditioning costs by up to 75 percent.[5] When all co-benefits are considered, green roofs provide benefits up to $14 more per square foot than traditional roofs.[40]
- **Tree Cover** – Trees can lower surface temperatures by providing shade and through evapotranspiration, which can reduce peak local summer temperatures by 2-9℉. Shady areas can be between 20-45℉ cooler than sunny areas, providing safe resting places outside. Additionally, a study found cities see benefits equivalent to $1.50-$3 for every $1 invested in tree planting.[40]
- **Gardens** – The planting of native plants—including along parking lots, streets, and in yards—can provide cooling effects.[5] Vertical gardens, also referred to as green or living walls, involves planting on walls to provide shade for buildings. This helps to cool the building and surrounding area.[46]
- Any **solutions that convert built environments to natural environments** such as forests, wetlands, and vegetation, can aid in lowering temperatures. Natural environments and green vegetation provide more shade, moisture, and evaporation than built environments, all of which help reduce temperatures.[40] At the same time, these systems sequester carbon, helping to minimize future warming.[40]

Co-benefits

In addition to the co-benefits related to water usage noted in the section above, these nature-based solutions help improve air quality by reducing air pollution and smog.[40] This helps improve public health and reduces risks for respiratory problems such as asthma.[5] Additionally, lower temperatures lead to less money and energy being spent on cooling costs. This helps save money for individuals and businesses, and also lowers emissions, helping to mitigate climate change.[5] These solutions also provide habitat for a variety of species.[5]

Current Projects

- In **Nashville**, Root Nashville is planting trees across the city in areas experiencing warmer temperatures. They have planted over 5,300 trees since October 2018, lowering temperatures between 1-4℉ on hot summer days. Their goal is to plant 500,000 trees by 2050.[47]
- Throughout the state of **Utah**, TreeUtah works to educate youth about stewardship and sustainability, while also planting trees to help clean the air and water and lower local temperatures. As of their 30-year anniversary in 2019, the organization has planted over 370,000 trees.[46,48]
- **Kansas City, Missouri**, installed over 450,000 square feet of green roofs throughout the city between 1999 and 2015, and is continuing to do so. As one of the U.S. cities experiencing the most intense urban heat island effect, city leadership was concerned and began investing in green infrastructure solutions to mitigate extreme heat while also providing water and air quality improvements.[49]

Conclusion

While context specific, the widespread implementation of nature-based solutions is a critical tool for addressing U.S. infrastructure needs in the face of climate change. Importantly, nature-based solutions generally do not increase greenhouse gas emissions, unlike gray infrastructure that is produced from energy-intensive materials (energy derived from fossil fuel combustion that emits greenhouse gases).

Around the country, organizations and communities are employing nature-based solutions, and the federal government is increasingly prioritizing nature-based solutions as well. For example, the US Fish and Wildlife Service Coastal Program is currently working on a plethora of projects, including restoring salt ponds to wetland habitats in the Don Edwards San Francisco Bay National Wildlife Refuge, supporting living shoreline development in many counties along the Florida coastline, and removing the Pond Lily Dam to restore natural stream flow and mitigate flooding in New Haven, Connecticut.[50,51] The U.S. Army Corps of Engineers' Engineering with Nature program works with communities around the country to combine natural and gray infrastructures.

Nature-based solutions are becoming more prevalent and widely accepted as infrastructure solutions to climate change. The federal government has the opportunity to build on this momentum through legislation, appropriations, and project management. To increase resilience to climate impacts, nature-based solutions should be seen as critical infrastructure, helping mitigate climate change and protect our communities.

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This fact sheet is available electronically (with hyperlinks and endnotes) at *www.eesi.org/papers*.

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