# POLICY OPTIONS FOR CLIMATE-RESILIENT INFRASTRUCTURE

C2ES CENTER FOR CLIMATE AND ENERGY SOLUTIONS

A new federal infrastructure package presents a critical opportunity to strengthen America's infrastructure against the growing risks posed by extreme weather and other impacts of climate change. Enhancing the climate resilience of the nation's infrastructure can substantially reduce future losses, benefiting public health, safety, quality of life, and prosperity. This policy brief outlines the benefits of climate-resilient infrastructure and criteria that should inform infrastructure planning and investment to enhance climate resilience. It identifies the types of infrastructure projects that can promote resilience while simultaneously achieving other climate and energy goals and recommends changes to existing federal policies and programs to ensure ongoing improvement to the climate resilience of America's infrastructure.

## BENEFITS OF RESILIENT INFRASTRUCTURE

Even without considering the impacts of climate change, the American Society of Civil Engineers estimates that failure to make necessary investments in infrastructure will cost the United States 2.5 million jobs and $4 trillion in GDP over this decade (2016 – 2025) and that the average household will lose $3,400 a year.[1] Recent events, however, illustrate how changes to the climate could result in even greater losses. Many parts of the country are currently rebuilding infrastructure damaged during the extreme weather events of 2017. Last year, the United States experienced 16 weather and climate disasters resulting in losses exceeding $1 billion each, with a record-breaking $306 billion in cumulative losses.[2]

All evidence suggests this trend will grow through at least the end of this century. Investing in resilience upfront is critical for long-lived infrastructure because the climate of 2050 and 2100 will look very different than today. A warmer, wetter atmosphere is expected to make rainfall more intense; extreme precipitation events could be two to three times more common by 2100 if global greenhouse gas emissions go unchecked.[3] Such long-term climate trends will take a toll on infrastructure. Freeze-thaw cycles tend to increase during warmer winters, summer temperatures will be hotter, and rising sea levels will potentially inundate coastal infrastructure.

Resilience is the ability to anticipate, prepare for, and respond to hazardous events or trends. Improving climate resilience involves assessing how climate change will create new, or alter, existing climate-related risks faced by communities, structures, and vulnerable populations, and taking steps to better address those risks.

For projects with a long design life, consideration of climate and weather projections can save taxpayers' money by reducing future disaster costs, extend the life of infrastructure projects, save lives in extreme weather events, and accelerate recovery afterward. In some cases, upfront investments in resilience can yield over a project's lifetime at least four times the savings from avoided damages due to extreme weather.[4] For example, projects to reduce wind and water damage in Florida were found to have avoided $81.1 million in losses when Hurricane Matthew struck while they only cost $19.2 million to implement.[5]

Fortunately, many of the features that would make an infrastructure project resilient provide other benefits as well. These benefits include reduced long-term fiscal

exposure for the federal government,[6] improved public health, and improved economic competitiveness. The world's top companies are already considering climate change impacts in their investments and prioritize areas that are starting to adapt and take action when locating their infrastructure. For example, Royal Dutch Shell is taking steps to ensure its facilities are resilient to climate change by identifying the vulnerability of existing assets and continuously adjusting design standards.[7]

## CRITERIA FOR DEVELOPING RESILIENT INFRASTRUCTURE

Climate resilience must be mainstreamed into infrastructure planning and investment. The following is a set of criteria that can help integrate climate resilience into the full range of infrastructure decision making. These criteria can inform infrastructure projects and investment selection (whether in legislation or by federal agencies and other decision makers), guide project design and development, and direct any proposed changes in permitting and review processes.

### INFORM DECISIONS WITH CLIMATE PROJECTIONS

Using the best available data on climate risks better informs project stages from design to construction and long-term maintenance. The frequency and intensity of precipitation, heat, storms, and other climate change impacts could grow dramatically over the extended time horizons for which infrastructure is often constructed. Future climate conditions affect design decisions for infrastructure in numerous ways, including the selection of construction materials that can withstand necessary temperature ranges, inclusion of stormwater management features designed to absorb a given level of rainfall, and designs for flood elevations to address specific floodwater depths.

Future climate projections can also be used to assess the vulnerability of projects in the design phase, and help identify strategies to improve resilience. Several federal agencies have developed guidance on conducting climate vulnerability assessments. One such guidance from the Federal Highway Administration was developed after working with state and regional transportation agencies across the country.[8] Those case studies, and others that followed, can guide the design of resilient infrastructure based on future climate conditions. A pilot project with the Minnesota Department of Transportation identified a diverse set of resilience options to help Minnesota prepare for an increase in flash flood risk projected through 2100. The options included expanding the size of culverts, buying upstream property to create an enhanced floodplain (which has the co-benefit of improved water quality), and converting culverts to bridges (which has the co-benefit of improved fish passage in public waters).[9]

The leading edge of climate vulnerability assessments is the use of downscaled climate model data to estimate future climate conditions over small spatial scales. This high-resolution data provides clarity on climate impacts that can improve project design, and it is already being used by public and private stakeholders to make infrastructure investment decisions.[10] When possible, downscaled data should be used to evaluate lifetime climate and weather risks for infrastructure projects. Downscaled climate model data is publicly available through several platforms, including the National Oceanic and Atmospheric Administration (NOAA), the national labs, and Cal-Adapt (for California only).

### OVERCOMING OUTDATED CLIMATE AND WEATHER DATA

Improving data on existing hazards and risks can better support resilient infrastructure if projections for future climate impacts are unavailable. This has been noted repeatedly in the case of floodplain maps generated by the Federal Emergency Management Agency (FEMA). These maps are required by Congress to support the National Flood Insurance Program (NFIP). They are meant to provide property owners and the public with updated information about riverine and coastal flood risks, however, FEMA has been unable to keep its maps up to date. A recent audit found that only 49 percent of FEMA's floodplain map database had been updated as of 2016.[11] This has serious implications for infrastructure siting as well as other planning. In Houston's southeastern suburbs, seventy-five percent of flood damages from 1999 to 2009 occurred outside of the official 100-year floodplains.[12] Improved floodplain maps would help site projects away from high flood risk or make design decisions that manage flood risk over a project's lifetime.

Project design can also incorporate precaution in mapping risk. An example comes again from floodplain mapping. Both public and private infrastructure today is commonly built outside the 100-year floodplain, or, if it must be built in the floodplain, flood risk reduction strategies are employed. Federal policy has incentivized this risk management primarily through the NFIP, but floodplain maps are constructed using historic values, which likely underestimate both the extent of the future 100-year floodplain and the depth of floods from future precipitation events. To account for this, infrastructure projects could be constructed with appropriate precaution, using 500-year flood levels rather than 100-year levels, or they could be elevated two to three feet above the 100-year flood level. Federal agencies were ordered in 2015 to follow those design guidelines in a Federal Flood Risk Management Standard (FFRMS), but that directive was revoked in August 2017.[13] Several states and local jurisdictions are already implementing similar guidelines, but infrastructure legislation should include new guidelines that replace the FFRMS and better reduce risk in infrastructure projects.

## BE TRANSPARENT ABOUT DATA AND DECISIONS ABOUT CLIMATE RISK

For public or private sector infrastructure projects to qualify for federal investment, the methodology used to assess risk and vulnerability and to inform design, construction, and maintenance should be made public, including the climate data used and how it informed decisions. Such data and decision-making considerations can be valued assets, informing the public of the climate conditions federally-funded infrastructure was designed for and how the new or repaired structure may contribute to local resilience efforts. For example, if a coastal highway is elevated to withstand two feet of sea level rise, public and private entities using that highway can design their own emergency response and resilience strategies with that scenario in mind.

Additionally, increasing the availability of climate data can assist public and private entities undertaking their own climate resilience planning, and it promotes collaboration among different actors. This is especially true when federal sources develop and share downscaled climate model projections. Local governments and small businesses would not typically have the resources for this kind of exercise, but they can benefit from a clearer understanding of the localized risks they might face. Leveraging federal dollars in this way is becoming more important as credit rating agencies start explicitly accounting for climate change in their rating methodologies.[14]

## PRIORITIZE FLEXIBLE AND ADAPTABLE PROJECTS

Future climate conditions are inherently uncertain because they depend upon future emissions of greenhouse gases that are, themselves, dependent upon global policies and economic factors that are constantly in flux. To avoid either over- or under-investing in resilience, it is important to prioritize infrastructure projects and designs that are more flexible and adaptable to future climate conditions.

Increasingly intense and frequent climate change impacts also demonstrate why infrastructure should be constructed and maintained with the expectation of increasingly extreme weather events going forward. In addition to being able to recover, infrastructure upgrades and construction should prioritize adaptability to changing conditions like longer frost-free seasons or increased intensity of precipitation.

Green infrastructure is one example of adaptive and flexible infrastructure. Communities and states across the country are harnessing ecosystem services to reduce infrastructure capital investments and choosing projects with reduced costs for construction, operations and lifetime maintenance, while also boasting improved resilience. These projects often have added public health benefits by improving water quality, air quality, and reducing urban heat island effects. These co-benefits can be especially important for vulnerable and underserved populations that tend to have a larger exposure to pollution and heat. The City of Philadelphia has relied on green infrastructure to address flooding challenges because it can be phased in over time, and design can be adapted from site to site based on the results of other pilot projects. Additionally Philadelphia's investments in green infrastructure have had an economic impact of nearly $600 million within the city, and they support 430 local jobs.[15]

## PLAN FOR RESILIENT OPERATIONS, MAINTENANCE, AND REPAIR

Many of the climate vulnerabilities that communities

now face are exacerbated by neglected infrastructure maintenance. A federal infrastructure bill provides an opportunity to reduce these vulnerabilities by funding the repair and upgrade of existing systems while considering climate impacts in those activities.

Surface transportation serves as a key example of the need for long-term planning for maintenance costs. The backlog of repair and replacement needs in surface transportation is widely recognized.[16] Climate change is likely to increase repair needs as freeze-thaw cycles and extreme precipitation become more common. Most transportation system maintenance is supported by local and state governments, but the federal Highway Trust Fund plays a role as well. Insufficient maintenance funding at all levels of government has contributed to the poor conditions of roads and transit systems today.

New construction specified in the bill should make allowances for funding the long-term operation and maintenance of the project. There will be few resiliency benefits if new project construction does not prioritize these maintenance measures to ensure they remain in good repair and functional for decades to come.

### ENSURE BENEFITS OF INFRASTRUCTURE INVESTMENT ARE EQUITABLY DISTRIBUTED

Investing in infrastructure that serves populations whose climate vulnerabilities are exacerbated by societal inequalities can be especially impactful. Resilient infrastructure is designed and constructed with consideration of vulnerable populations such as senior citizens, children, people with disabilities, low-income households, and those with restricted access to cars or public transportation. Infrastructure funding should be prioritized based on the number of homes affected and potential for preventing loss of life, rather than the financial value alone of the assets that are at risk or affected.

New projects, repair, and maintenance should be concentrated in areas where the population would most benefit from upgraded infrastructure. In extreme events, the same vulnerable populations have been disproportionately affected time and time again. Nearly half the deaths in Superstorm Sandy were among people ages 65 and older,[17] while Hurricane Harvey affected low-income neighborhoods more because those families lived in flood-prone areas of Houston.[18] Consideration of these vulnerabilities in highway and flood control projects can save lives. Mass transit projects can also better connect the elderly, low-income, or otherwise isolated people with job opportunities, schools and their community.

Choosing infrastructure projects that are decentralized and more reliant on long-term maintenance (like the green infrastructure discussed in the above section) multiplies the local impact of infrastructure investments by providing long-term, local jobs that rely upon general skills rather than specialized education.[19]

### RESPECT EXISTING ENVIRONMENTAL LAWS AND REGULATIONS

Federal and state laws and regulations protect the nation's water quality, air quality, and endangered species. While the need for infrastructure investment is critical, these environmental considerations should not be abandoned. Opportunities to streamline existing permitting processes can and should be explored, but robust environmental review is necessary to identify existing vulnerabilities or changing conditions that could threaten infrastructure, and they should continue to be used.

## PRIORITY INFRASTRUCTURE PROJECT TYPES FOR RESILIENCE

Infrastructure that increases climate resilience while simultaneously enabling technology innovations and clean energy will protect America's economy for years to come. The project types listed below should be prioritized by Congress and the Administration in distributing funding and prioritized by federal agencies who may ultimately be selecting individual projects for federal support. Each of these infrastructure types could make the United States more resilient to climate change and extreme weather (now and in the future) while delivering other economic and environmental benefits.

- **Upgrading electricity transmission and distribution infrastructure**
  Example projects include hardening existing systems, building new wires to connect clean energy resources with demand centers, and deploying advanced metering, "smart meters," infrastructure. DOE's Partnership for Energy

## BOX 1: The GHG mitigation-resilience connection

Climate and weather-related risks will grow in proportion to atmospheric greenhouse-gas concentrations. Reducing emissions can mitigate future climate impacts, extending the service life and increasing the resilience of infrastructure constructed today.[20] But unchecked emissions make it less likely that today's resilience investment will pay dividends in the future.

For that reason, as an important complement to strengthening the climate resilience of the nation's infrastructure, any major new infrastructure program should favor investments that help to reduce greenhouse gas emissions. Many project types can reduce emissions while simultaneously increasing resilience; including for example, electricity infrastructure that serves zero carbon generation sources, alternative transportation fuels and modes, and water infrastructure improvements that reduce leaks and promote efficiency.

Projects could be required to consider greenhouse-gas emissions as part of the design and permitting process. Various methodologies for this analysis currently exist, for example the Federal Energy Regulatory Commission (FERC) estimated the downstream change in greenhouse-gas emissions to result from a proposed natural gas pipeline.[21] Investment priority should be given to projects with the lowest downstream emissions.

Sector Resilience, a voluntary partnership between the federal government and industry, found via industry assessments that transmission and distribution systems are the most vulnerable component of the nation's electricity system.[22] Making these components more resilient to storms, wildfires, and other climate change impacts, through hardening or smart meters, reduces the likelihood and duration of power outages that harm the economy. Also, expanding transmission systems to better utilize clean energy can increase fuel diversity in the power sector, improving resiliency to extreme events.

- **Upgrading and expanding alternative transportation modes and fuels**
  Example projects include capital improvement in existing mass transit systems, adding bike lanes to existing streets, developing high-speed rail corridors, and expanding electric vehicle charging infrastructure. Communities with multiple modes of transportation are more resilient to disruptions on any individual system. This can improve local business continuity and protect economic productivity. Having robust alternative transportation options also reduces vulnerabilities in low-income and other underserved populations who may have limited evacuation options when severe storms pose extreme danger. Similarly, communities with diverse vehicle fuel options are more resilient to short-term disruptions in fuel supply or price.
- **Modernizing internet and telecommunications infrastructure**
  Communities with up-to-date and robust telecommunications systems are better equipped to respond to disasters and resume normal activities faster. Other economic sectors can also build upon modern telecommunications to enhance their own resilience. For example, grid operators using advanced communications technologies can de-energize segments of the grid ahead of a storm to shorten outage durations.
- **Upgrading water infrastructure and expanding capacity via green infrastructure**
  Example projects include repairing and replacing pipes at risk of leakage and emphasizing nature-based systems, such as wetlands, trees, and other vegetation when expanding capacity. Some 14 – 18 percent of treated water is lost to leaks, wasting water and the energy used to transport and treat it.[23] Repairs to water distribution systems could reduce these losses. For systems that need expanding, either to accommodate growing populations or to address water quality violations, green infrastructure should be used to the fullest extent possible. These adaptive systems can grow over time, which makes them an appealing

low-cost resilience strategy, while also reducing flooding impacts, cooling cities, improving water quality, storing carbon, and providing other local benefits. This type of infrastructure is particularly well suited to upgrades to water infrastructure.

## MODIFYING EXISTING PROGRAMS FOR RESILIENCE

Resilience can be best achieved when it is integrated into existing processes. Many existing federal programs and policies already address resilience, and small adjustments to others would further enhance resilience. Enacting modifications to expand these programs via legislation would ensure that resilience is enhanced on an ongoing basis.

While not intended to be comprehensive, the following list is meant to demonstrate the variety of programs that exist and the diversity of infrastructure types in which resilience can be included.

- The federal Low Income Home Energy Assistance Program (LIHEAP) is a grant program administered by the Department of Energy that funds weatherization improvements for low-income homes. These energy efficiency upgrades not only lower homeowners' energy costs, but they can make homes more resilient to power outages that can accompany increasingly strong storms.
- The Biggert-Waters Flood Insurance Reform Act of 2012 established, among other things, a Technical Mapping Advisory Council for the Federal Emergency Management Agency (FEMA). That council recommended FEMA update its mapping capabilities to use high-resolution data generating by LIDAR and other emerging technologies, and develop mapping standards based on future conditions.[24] Funding the implementation of these recommendations would increase risk awareness and improve the quality of information used to make decisions about managment of flood risk in affected communities.
- Federally-supported climate science and data collection is critical for resilience planners. The U.S. Climate Resilience Toolkit and related data products from NOAA support resilience planning by public and private entities. Many federal agencies already conduct research related to adaptive and resilient materials and technology and could grow these efforts with additional federal support.
- The Water Infrastructure Finance and Innovation Act of 2014 established the WIFIA program, administered by the EPA, that provides federal loans for large drinking water and wastewater projects. Increased funding and an added emphasis on using green or more adaptive infrastructure designs would improve resilience.
- EPA's Clean Water State Revolving Funds provide, in practice, federal capitalization of state clean water infrastructure banks that support clean water projects, including those with resilience benefits like green infrastructure and estuary conservation. Added funding could better empower states to initiate more resilient infrastructure projects.
- The U.S. Department of Agriculture houses the Rural Utilities Service, which provides loans and funding for infrastructure projects in rural areas, including water, electricity, and telecommunications infrastructure. An added emphasis on residential energy efficiency, distributed renewable energy, and broadband could improve resilience in rural communities.
- In 2015, federal agencies were directed by executive order to establish a Federal Flood Risk Management Standard. This directive, which was revoked in 2017, would have ensured that federal investments went to projects built to withstand a greater level of flooding than the typical 100-year floodplain maps anticipate. Codifying the FFRMS that agencies had begun implementing in 2015 – 2016 would increase resilience of new federal investments.
- The federal Highway Trust Fund leverages federal dollars to support construction and maintenance of local surface transportation systems like highways and transit. The fund is financed primarily through an excise tax on motor fuels, but the tax rate has not increased since 1993 and does not keep pace with inflation. Updating the motor fuels tax to at least account for inflation since 1993 would generate greater funds for

infrastructure. Further modifying the Highway Trust Fund to devote a greater share of resources to public transit and highway maintenance would further increase community resilience by supporting multimodal systems.

- Private Activity Bonds (PABs) are exempt from federal income tax which helps lower financing costs for privately-owned projects that have public benefits. Expanding the list of projects that qualify for PABs to those that meet resilience criteria and enhance community resilience (like our priority infrastructure project types listed above) would accelerate private investment in resilient infrastructure.

Other legislative action may be needed to remove existing barriers to infrastructure resilience. For example, the Stafford Act of 1988 could be amended to better support hazard mitigation activities and reduce the risk of natural disasters occurring from climate- and weather-related events. We support a conversation into these types of national resilience policy reforms but recognize they are likely beyond the scope of infrastructure legislation and for that reason are not introduced here.

## CONCLUSION

The economic prosperity of the country depends upon resilient infrastructure. Paying upfront for added climate and weather resilience can yield large benefits over time. State and local governments are already experimenting with incorporating resilience into infrastructure design. Federal leaders can work in partnership across these levels of government to identify best practices and enhance resilience across the country.

An infrastructure package provides a window of opportunity for that action. Any specific infrastructure projects included in new legislation should be screened using the type of resilience criteria identified here. Further, federal agencies should be directed to use such criteria when approving projects moving forward. These criteria should consider the data used in developing infrastructure plans and prioritize flexible, equitable projects while protecting long-term interests by planning for operations and maintenance costs and protecting the environment.

Many infrastructure project types should be prioritized in order to increase the resilience of communities across the country and to spur technology and business innovation in clean energy. These project types are resilient and clean electricity, robust alternative transportation systems, modern telecommunications systems, and efficient and adaptive water infrastructure.

Implementing resilience criteria and funding resilience projects need not require new federal programs and policies. Many existing programs already address resilience, and others can address resilience with small modifications. Any major infrastructure package enacted by Congress should ensure that taxpayer dollars are spent responsibly, and that infrastructure projects authorized and funded will serve the country for decades to come.

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