WHITE PAPER

OFFICE OF MANAGEMENT AND BUDGET

BUDGET EXPOSURE TO INCREASED COSTS AND LOST REVENUE DUE TO CLIMATE CHANGE: A PRELIMINARY ASSESSMENT AND PROPOSED FRAMEWORK FOR FUTURE ASSESSMENTS

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Introduction

The climate crisis poses a serious threat to the United States economy and human welfare, with a narrowing timeframe to make strategic investments to avoid the most catastrophic impacts. Acute effects such as extreme weather events, changing precipitation patterns, and impacts to air and water quality caused by climate change all disrupt supply chains, changes to food production and supply can result in cascading impacts disrupting services (Jay et. al, 2018). Climate change also adds risks to stressors including deteriorating infrastructure, land-use changes, and population growth (Clarke et. al, 2018). Without action, climate change threatens the Nation's economy, national security, essential services, and the Nation's fiscal health. The Fourth National Climate Assessment (NCA4) notes that:

> *Climate change is transforming where and how we live and presents growing challenges to human health and quality of life, the economy, and the natural systems that support us. Risks posed by climate variability and change vary by region and sector and by the vulnerability of people experiencing impacts.* (*Jay et. al, 2018.*)

To help address threats that climate change poses to the economy, President Biden signed Executive Order (E.O.) 14030 "Climate-Related Financial Risk" on May 20, 2021. Section 6(b) of the E.O. 14030 directs "[t]he Director of Office of Management and Budget and the Chair of the Council of Economic Advisers, in consultation with the Director of the National Economic Council, the National Climate Advisor, and the heads of other agencies as appropriate, [to] develop and publish annually, within the President's Budget, an assessment of the Federal Government's climate risk exposure." This report supplements materials within the President's Budget required by Section 6(b) of the E.O. 14030.

The impacts of climate change on businesses and communities are broad; escalating costs and lost revenue as a direct or indirect result of a changing climate are significant and varied. Some of the most severe harms from climate change will fall disproportionally upon socially and economically vulnerable populations, including racial and ethnic minority communities (Ebi et. al, 2018). The Federal Government and State governments play a critical role in helping families, businesses, and communities recover from the impacts of extreme weather events – often acting as an insurer of last resort. Communities and businesses also face both immediate hazards with increasing risks over time, such as sea level rise. The Federal Government must ensure that Americans have access to such things as food, housing, and healthcare that is safe and affordable as well as access to critical transportation and communication infrastructure. Climate change increases the need for Federal funding in these areas.

As broad economic damages from climate change grow, so does the impact of the climate crisis on the Federal Budget. The Federal Government's budget is directly and substantially at risk from expected lost revenues and increasing expenditures due to climate change damages in coming decades, such as increasing costs from physical damages to our Nation's infrastructure and healthcare expenditures, the instability of certain subsidized insurance programs, growing costs of disaster relief, and accelerating instability that threatens global security.

White Paper Scope and Relationship to Executive Order Sec. 6(a) Long-Term Budget Outlook report

This white paper supports the "Budget Exposure to Increased Costs and Lost Revenue due to Climate Change" *Analytical Perspectives* chapter of the 2024 President's Budget. The first half of this report provides updates to the prior year assessments of the Federal Budget's exposure to climate risk. These assessments rely on today's limited climate financial risk tools. While there is a rich literature on climate projections, the availability and accessibility of tools and other necessary data to use these climate projections to evaluate the Federal Budget's exposure to climate risk are limited. This report includes updated analysis on flood risk to Federal facilities and a new assessment on the impact of climate change on the Low Income Home Energy Assistance Program (LIHEAP). These assessments should not be interpreted as definitive results, but rather illustrative examples of analysis, highlighting the need for further research, new data, and new tools that can accurately measure climate financial risk.

In response to the need for a consistent and repeatable methodology for future assessments, the second half of this report outlines a common framework for agencies to assess the budget exposure to climate risk of federally administered programs, federally owned assets, and operations and mission, including an approach to improve climate financial risk tools. This section covers the following topics: 1) current approaches used by Federal agencies for assessing climate risk; 2) climate data and modeling that are currently available to agencies; 3) a proposed common framework to assess climate-related financial risk and necessary technical inputs; and 4) a discussion of next steps to further develop the common framework. Analysis presented in this white paper is expected to be revised in future years as new climate and financial risk modeling capabilities are incorporated and data quality and availability are improved. This assessment is intended to provide transparency on the current modeling and data and show where gaps exist, contributing to an iterative process of improving data and methods concerning the Federal Budget's exposure to climate risk.

This assessment is complementary to the analysis directed by Section 6(a) of E.O. 14030, which requires "the Director of OMB, in consultation with the Secretary of the Treasury, the Chair of the Council of Economic Advisers, the Director of the National Economic Council, and the National Climate Advisor, [to] identify the primary sources of Federal climate-related financial risk exposure and develop methodologies to quantify climate risk within the economic assumptions and the long-term budget projections of the President's Budget." The work directed by Section 6(a) takes a broad, macroeconomic view of the impact of climate risk on the economic assumptions used within the President's Budget, which includes gross domestic product (GDP), and the long-term budget outlook.

Although the long-term budget projections are not directly incorporated in this report, the impact of climate change on macroeconomic trajectories in turn impacts the projections of Federal revenue and expenditures in the President's Budget. The "Long-Term Budget Outlook" *Analytical Perspectives* chapter of the President's Budget assesses the magnitude of this indirect, macroeconomic channel through which climate risk affects the long-term fiscal outlook. Therefore, together the analyses of Section 6(a) and Section 6(b) illustrate the multi-faceted impact of climate change on the Federal Budget.

Limitations and Interpretation of Results

In an effort to better understand the risks that climate poses to the Federal Budget, the Office of Management and Budget (OMB) continues to work with partners across the Federal Government to further the assessment of climate-related financial risks. While projections of expenditures are developed, the primary contribution of this assessment is evaluating the limitation of current methods and data. In the 2023 President's Budget, OMB published an assessment that included six types of climate risks: (1) disaster relief, (2) flood insurance, (3) subsidies for Federal crop insurance premiums, (4) healthcare expenditures, (5) wildland fire suppression expenditures, and (6) flood risk to Federal facilities. Excluding flood insurance and the flood risk to Federal facilities, Table 1 shows that the combined projected increase in Federal expenditures across these topics ranged for the late 21st century from $26 billion to $134 billion (2021 dollars) annually, a significant underestimation of the total exposure to the Federal Budget due to the limitations of today's climate financial risk tools. In addition to these topics, the 2023 President's Budget included information, primarily qualitative analysis, on other areas of the Federal Budget's exposure to climate change including the Federal lending portfolio for single-family housing, national security, infrastructure risk, ecosystems, and biosecurity.

TABLE 1: QUANTIFIED FEDERAL CLIMATE RISK EXPOSURE PROJECTED CHANGE IN ANNUAL EXPENDITURES OF ASSESSED PROGRAMS
(in billions of 2021 dollars[1])

Assessment Topic	Mid-Century			Late-Century		
	Central Measure[3]	Low	High	Central Measure[3]	Low	High
Crop Insurance[2]………………………………….	NA			1.3	0.3	2.2
Coastal Disasters………………………………	15.3	4.6	34.0	51.8	22.9	98.5
Healthcare……………………………..……….…	1.0	0.2	1.9	11.9	0.9	22.9
Wildland Fire Suppression…………………….	1.7	0.9	2.4	3.9	1.6	10.0
Total for Assessments[4]……………………………	**18.0**	**5.7**	**38.3**	**68.8**	**25.7**	**133.6**

[1] The summary table of the assessments within the 2023 President's Budget used 2020 dollars, hence the values in this table, which are in 2021 dollars, are slightly higher due to inflation.

[2] The crop insurance analysis was only conducted for late century.

[3] The median of all wildland fire suppression simulations is used in the "Central Measure" column, so outliers in the "Higher" scenario are not overemphasized in the results. All other topics use the mean as the central measure.

[4] Multiple Federal financial risks are not included in this table due to the nascent ability to quantify future expenditures in this field.

Within this assessment, we provide updates to the Federal Budget's exposure to climate risk. The analysis on flood risk to Federal facilities now provides an estimate of the replacement value for a select set of Federal facilities, and incorporates forward-looking climate scenarios for flooding; however, given the limitations of the current climate financial risk tools, the assessment could not evaluate site-specific risks. As such, this analysis is illustrative of the process for developing projections, rather than an official Government estimate of the projected losses. This analysis is in effect, a test case used to determine whether current modeling tools can adequately model physical climate financial risk to Federal programs.

This report adds the Low Income Home Energy Assistance Program (LIHEAP)—a Federal program that assists low-income households with heating and cooling costs—to the assessment of Federal financial climate-risks. The analysis on LIHEAP is preliminary and unable to account for important variables that should be included in future research. No updated projection is provided for the National Flood Insurance Program due to last year's introduction of Risk Rating 2.0.[1] As a result of this methodological update, the National Flood Insurance Program is required to be "actuarially sound", i.e., on average, premiums are equal to losses, and as such there is no projected increase in net program expenditures resulting from climate change.

[1] For more information on Risk Rating 2.0, go https://www.fema.gov/flood-insurance/risk-rating.

Background

The "Federal Budget's exposure to climate risk" is an umbrella term that captures how climate change can impact Federal expenditures and revenue. Within this paper, we primarily focus on the expenditures for specific areas where the Federal Government is vulnerable to climate-related financial risk. Climate-related financial risk includes both the physical risks of climate change—resulting from climatic events, such as wildfires, storms, and floods—and transition risks that result from policy action taken to transition the economy off of fossil fuels. The extent to which expenditures of the Federal Government are impacted by climate change may depend on the nature of the Federal program or type of Federal funding being outlaid. Federal funding generally falls into the categories of discretionary or mandatory.

- Mandatory funding is provided by an authorizing law, which allocates money each year or for a set of years to be spent on specified activities or goods. This funding may have a set amount for a specified time period or provide "such sums as necessary" for the operation of a Federal program.
- Discretionary funding is money provided in annual appropriations. Supplemental funding may occur outside of annual appropriations when there is an urgent need for funding, such as the series of supplemental appropriations related to the pandemic or additional assistance after an extreme weather event.

For a comprehensive overview of the structure and processes of the Federal Budget, readers can refer to the Analytical Perspectives Chapter "Budget Concepts" of the President's Budget. The Federal Government's direct support can take multiple forms including direct payments, loans, and insurance. The Federal Government offers direct loans and loan guarantees to support a wide range of activities including home ownership, higher education, small business, farming, energy, infrastructure investment, and exports. Through its insurance programs, the Federal Government insures deposits at depository institutions, guarantees private-sector defined-benefit pensions, and insures against some other risks such as flood and terrorism. More information on Federal credit and insurance programs is available in the Analytical Perspective Chapter "Credit and Insurance" of the President's Budget.

Both mandatory and discretionary funding in the Budget can be impacted by climate change. However, how the Budget is impacted may not always be to increase funding. In some cases, programs, like Medicare, may experience higher outlays (spending) since the program's funding is described as "such sums as necessary," which do not cap the outlay amounts. However, for Federal activities that have funding amounts set in statute, in the short-run, expenditures cannot exceed the designated statutory amount. These programs may have to serve a smaller number of recipients or lower the benefits per recipient when faced with increased demand for the program. This may apply to appropriated programs, such as the Low-Income Home Energy Assistance Program, if funding levels do not fully adjust to reflect the changes in heating and cooling expenditures due to changes in temperature. In the long-run, if Congress increases funding to Federal activities more vulnerable to climate change, these decisions may lead to trade-offs within the Federal Budget, such as reductions to other Federal programs or increased borrowing. These unknown future tradeoffs highlight the complexities of examining the Federal Budget's exposure to climate risks.

Example Budget Areas Vulnerable to Climate Risk

While currently available methods and data do not allow us to accurately quantify the Federal Budget's full exposure to climate risk, we can qualitatively describe expected types of exposure. Here we describe a few critical areas where the Federal Government is vulnerable to budgetary impacts from climate change. These examples are intended to provide a broader perspective of different types of budget risk, in addition to the detailed assessments provided in the subsequent chapters.

Disaster Response: Extreme weather events are increasing in frequency and intensity (Hayhoe et. al, 2018), which presents continual challenges in keeping people and property safe. Since 1980, there have been 341 weather and climate events with an estimated cost of at least $1 billion *each* (to the entire economy, not just the Federal Government), when adjusting for inflation to benchmark the year 2022. The total estimated cost from these 341 events is $2.475 trillion (NOAA, 2023). The years 2022 and 2021, respectively rank as the third and fourth most expensive years, with the year 2022 costing $165 billion and the year 2021 costing $155 billion.[2] Moreover, each of the last three years was in the top six most expensive years since 1980 (*ibid*).

While the Federal Government does not fully bear the burden of these costs, Federal disaster response costs the Federal Government billions of dollars every year. Federal, State, and local governments have provided aid in the amount of 47 percent of the economic damages from major natural disasters between January 1989 and September 2022 (Zandi et. al, 2022). The Disaster Relief Fund (DRF) is appropriated funding for response and recovery activities for disasters eligible under the Robert T. Stafford Disaster Relief and Emergency Assistance Act. These funds can be used for: emergency protection; debris removal; repair and restoration of qualifying disaster-damaged public infrastructure; hazard mitigation; financial assistance to survivors; and Fire Management Assistance Grants for large wildland fires (Federal Emergency Management Agency, n.d.). In addition to the Disaster Relief Fund, there are multiple programs throughout the Federal Government that support a diverse range of disaster response and recovery, including wildland fire suppression, rental assistance (Federal Emergency Management Agency, 2022), emergency food assistance (Food and Nutrition Service, n.d.), and assistance for losses of crops or livestock (Farm Service Agency, n.d.).

Therefore, while we do not currently have a quantification for all the fiscal risks faced by the Federal Government caused by the increase in frequency and intensity of natural hazards due to climate change, the current knowledge about these costs across the economy, and the billions now spent annually in expense of Federal disaster response and recovery efforts, indicates the potential for substantial future costs from climate change.

Infrastructure: Infrastructure built to withstand historical climate-related hazards may not be capable of enduring the more severe conditions projected for the future (Avery et. al, 2018). Longer-term impacts of climate change could include damage to roadways from higher temperatures, causing asphalt to buckle and the need more frequent repairs (Jacobs et. al, 2018); impacts to water infrastructure due to drought and higher temperatures, which not only worsen ground water depletion but can also weaken earthen dams and levees (Lall et. al, 2018); negative

[2] The most expensive year was 2017 ($373 billion in 2022$), the year of Hurricane Harvey, Hurricane Irma, and Hurricane Maria. The second most expensive year was 2005 ($254 billion in 2022$), the year of Hurricane Katrina.

impacts on thermoelectric power generation, which require surface water for cooling; and declines in snowpack and changes in snowmelt timing in the western United States, which could affect the availability of hydropower generation (Zamuda et. al, 2018).

Drought and high temperature are not the only climate-related threats to infrastructure. Rising frequency of heavy precipitation and strong winds present perils for infrastructure, both in coastal and inland regions. Intense rainfall has the potential to wash away bridges and roads and cause tunnels for utilities and transportation to become inoperable (Jacobs et. al, 2018). Severe flooding has the potential to deteriorate or cause breaches in dams or levees (Lall et. al, 2018). More frequent flooding and other extreme weather events, including severe cold snaps, also can damage energy infrastructure, causing more frequent and longer power outages (Zamuda et. al, 2018). Additionally, sea-level rise presents severe risks to coastal infrastructure, due to increased risk of coastal flooding.

Climate change is expected to impact Federal expenditures relating to infrastructure in multiple ways. For example, the Army Corps of Engineers, the Bureau of Reclamation, and the Tennessee Valley Authority maintain and repair the water resource? infrastructure that they own, while the Power Marketing Administrations and the Tennessee Valley Authority maintain and repair the transmission lines that they own. A large flood can damage some of these assets, or otherwise affect the ability of these agencies to make water and power available to their customers. Similarly, a drought can increase the cost that the Bureau of Reclamation incurs in those watersheds where it purchases water for fish and wildlife. Thus, in those parts of the country where the incidence of large floods or other extreme weather events due to climate change will increase, Federal expenditures for these agencies may also increase. Additionally, State Departments of Transportation, which receive the largest share of Federal highway formula funding, may need to use a larger amount of their Federal funding to make projects resilient to climate change. This, in turn, may reduce the amount of Federal funding available for other transportation projects. In addition, climate change impacts such as increased flooding and other events may increase the number of projects eligible for the Federal Highway Administration's Emergency Relief (ER) Program, which helps States repair or reconstruct highways damaged by natural disasters or catastrophic failures. The Federal Government may need to provide additional funding to repair or reconstruct these assets when they are damaged, or make them more resilient than originally built or purchased.

<u>Healthcare</u>: The scientific literature has examined health impacts from climate change in several key areas: temperature-related death and illness; changes to air quality; extreme weather events; vector-borne diseases; water-related illness; food safety, nutrition, and distribution; and mental health and well-being. For instance, more frequent, severe, prolonged extreme heat events will lead to elevated temperature exposure and increased heat-related deaths and illnesses (Ebi et. al, 2018). Worsened air quality from surface ozone and higher pollen counts will elevate the risk of cardiovascular and respiratory illness (Nolte et. al, 2018). Climate change is also expected to alter the risk of vector-borne disease by changing the distribution of existing disease vectors and causing new vector-borne pathogens to emerge (Rocklov and Dubrow, 2020). All of these pathways can cause an increase in both premature death (mortality) as well as non-fatal health problems (morbidity). Higher morbidity rates in particular cause healthcare utilization to grow over the long-

term, increasing total healthcare expenditures by private insurers as well as public programs like Medicare and Medicaid.

Ecosystem Services and Biodiversity: All Americans depend on the services that ecosystems provide, including clean air and water, food and resources, and support for cultural heritage and livelihoods. Climate change is impacting ecosystems in multiple ways, including: losing the capacity to buffer impacts of extreme events, altering the plant and animal life that inhabit regions of the United States, changing the timing of biological events, and reducing the ability to regulate water and air quality (Lipton et. al, 2018). These impacts are closely tied to how plant and animal species are responding to climate change—many species are unable to cope with these disturbances, leading to permanent extinctions (*ibid.*). Climate impacts, for instance, affect forest ecosystems, which in turn can affect the timber supply and the Federal Government's financial management of those resources (*ibid.*). In addition, many ecosystems provide important resilience functions for communities (*ibid.*). For example, healthy, intact salt marshes can buffer coastal communities from inundation. Financial risks to the Federal Government for programs that help support ecosystem services and species protections are very broad and difficult to monetize. Climate change is also shifting and often exacerbating the range of invasive species, which creates additional cost for land management agencies seeking to maintain native biodiversity and healthy ecosystems (*ibid.*). Both mitigation and adaptation actions by the Federal Government, along with State, local, tribal governments, and private organizations, will be needed to curb the worst effects of climate change on ecosystems within the United States.

National Security: Increasing temperatures, changing precipitation patterns, and more frequent, intense, and unpredictable extreme weather conditions caused by climate change are exacerbating existing risks and creating new challenges for Department of Defense (DOD) missions, plans, and installations (Department of Defense, 2021). Climate change is also shaping the strategic environment in which the DOD operates. Climate change impacts, when combined with other stressors, are likely to contribute to political, economic and social instability internationally (*ibid.*). The challenges presented by climate change may necessitate changes within the Federal Budget for national security.

Flood Risks to Federal Civilian Facilities

Introduction

The facility portfolio held by the Federal Government is substantial. Between domestic and international holdings, the Federal Executive Branch owns or leases more than 285,000 buildings[3], 2.8 billion square feet of buildings, over 537,000 structures, and over 27 million acres of land, with annual operating costs in excess of $36 billion (Federal Real Property Council, 2021). Just under half of these annual operating costs are for Department of Defense-run assets. The total reported replacement value of Federal property is estimated at nearly $1.9 trillion.[4] Federal facilities face a number of climate-change-enhanced hazards, including increased risks of flooding, extreme weather events, and fire. For example, following Hurricane Katrina, in only one year $38 million was needed to repair more than 83 damaged Federal facilities (Congressional Research Service, 2007). This shows that better data and modeling is needed to evaluate the true cost of climate change to Federal facilities.

Floods caused over $162 billion in property damage in the 2010s (inflation-adjusted to 2020 dollars) (Grimm, 2020). Flood damage from heavy downpours is projected to increase throughout the country. When adjusting for the impact of a changing climate over the next 30 years on flood risk, recent research finds that average projected annual losses to residential homes within the contiguous United States will increase 67 percent to $34 billion[5] (First Street Foundation, 2021). Similar to residential homes, the risk of flooding to federally-owned buildings and structures could increase due to hazards enhanced by climate change. In each of these cases, increased risk of flooding also increases risk of financial loss, as well as the Federal Government's capacity to provide services.

The report *Global and Regional Sea Level Rise Scenarios for the United States* projects sea level rise (SLR) through 2150 (Sweet et. al, 2022). Relative to its previous iteration five years ago (Sweet et. al, 2017), *Global and Regional Sea Level Rise Scenarios for the United States* (Sweet et. al, 2022) has greater confidence in its estimates of SLR by 2050. The increased confidence is a result of advancements in sea level science, leading hindcasts to more closely match historical SLR data (*ibid*.). By 2050, the sea level along the U.S. coastline is projected to rise 10–12 inches on average, equal to the rise measured from 1920 to 2020[6]. In other words, the next thirty years are expected to experience as much sea level rise as the past eighty years. A rise in sea level expands the coastal floodplain, causing increased frequency and magnitude of coastal flooding and compounding damages from storm surges. In 30 years, the frequency of "moderate" high tide flooding—which often causes damage—is expected to increase from 0.3 events annually at a

[3] As defined by the General Services Administration (2022), "A building is a constructed asset that is enclosed with walls and a roof that provides space for agencies to perform activities or store materials as well as provides space for people to live or work in." Structures do not fit the definition of building and include a wide range of types, including but not limited to parking structures, communication systems, harbors and ports, and utility systems.

[4] This is only for CFO agencies, which are the 24 Federal agencies mentioned under 31 U.S.C. 901.

[5] These projections assume climate change under the Representative Concentration Pathway 4.5, which assumes that warming stabilizes by 2100. The analysis includes homes that may or may not have federally backed mortgages.

[6] The amount of SLR rise differs by coastal locations due to factors specific to the areas, including regional ocean factors (e.g., wind patterns, ocean currents, and ocean temperatures), regional gravitational fields due to the melting of land-based ice, and local land elevation changes (e.g., land subsidence, tectonic uplift, or human development).

national level to 4 events annually, with some places experiencing even greater increases in frequency (*ibid.*).

This assessment provides projected effects caused by climate-change-enhanced flood hazards to federally owned civilian facilities through the years 2032 and 2052. Additional analysis in the assessment shows projected effects from SLR to these Federal facilities for mid-century and late-century under two SLR scenarios. Given the current data and modeling available, this assessment has significant limitations, and the projected losses and exposure should be interpreted as preliminary and partial, such that all we can currently state with confidence is that Federal facilities are exposed to flood risk. The numeric estimates in the tables of this section are for illustrative purposes only and are not suitable for decision-making, due to the fact we currently lack the data required to make robust projections of exposure and loss. The numeric results are presented to provide transparency of the data and modeling currently available through the Federal Government and to describe the data gaps that currently exist. Limitations and caveats are described with each respective flood risk assessment (i.e., fluvial, pluvial, and coastal flooding; and sea level rise inundation).

The numeric estimates in the tables of this section are for illustrative purposes only and are not suitable for decision-making, due to the fact that we currently lack the data required to make robust projections of exposure and loss. The numeric results are presented to provide transparency of the data and modeling currently available through the Federal Government and to describe the data gaps that currently exist.

Flood Risk Assessment

This analysis uses the Federal Real Property Public Dataset, which is a subset of the data within the Federal Real Property Profile Management System (FRPP MS). Currently, there is no comprehensive dataset for all buildings and structures on Federal land. However, FRPP MS is an inventory of Executive Branch agency real property assets within and outside the United States, including improvements on Federal land, except when otherwise required for reasons of national security (General Services Administration, n.d.). Annual data reporting is a decentralized process, to be executed within base agency resources and dependent upon the activities and work processes of each Federal Department and agency within a standardized set of definitions. Further, the data reported are subject to agency-specific verification processes; FRPP MS is not an annually audited set of data as part of the financial reporting process. The dataset was established to form a basic inventory of Federal assets that provides an annual snapshot in time; similar information was not available prior to 2005.

OMB acknowledges here that the FRPP MS public dataset is not an appropriate dataset to perform the flood risk analysis of Federal facilities. OMB believes the illustrative value of the analysis can help advance future analyses by highlighting the extensive data gaps that currently exist within the analytical framework employed here.

The caveats attendant to FRPP MS data as used in this analysis are:

1) *Individual real property assets are withheld from FRPP MS Public Dataset for national security reasons.* Examples of assets and asset types that are eliminated in the public dataset include all Department of Defense and civilian high security assets. Elimination of assets for national security reasons results in the public dataset containing only a portion of the assets in the Federal inventory. The FY 2021 public dataset contains 100,540 buildings owned by the Federal Government (General Services Administration, 2022). However, the FY20 aggregated summary of all federally owned civilian and defense real property indicates 252,277 buildings (General Services Administration, 2021). The same summary contains an aggregated total of 449,695 structures owned by the Federal Government (General Services Administration, 2021), while the number of individual structures in the public dataset is 158,100 (General Services Administration, 2022). Because the Federal Government owns a wide range of real property and it is unknown whether the public dataset is a representative sample of the full Federal portfolio of assets, we are unable to extrapolate the total flood risk exposure and potential impact on value on the Federal portfolio. Further, assets withheld from the public dataset for national security reasons, e.g., military installations, are assumed to be dissimilar from real property operated for civilian uses, e.g., office buildings or museums, which would further impact estimating.

2) *Agencies are not required to report longitude and latitude information on an individual asset if the asset is part of a Federal campus.* Each Federal department and agency is required to report data at the individual asset level as part of the inventory. However, data reporting instructions for longitude and latitude provide departments and agencies with the flexibility to report all assets located on a single campus/within a campus boundary as the street address of the facility (e.g., the main gate). This allows for reporting of assets without additional security concerns for specific buildings located on a campus. The centralized location reporting has a significant impact on a study of this nature, given the differing topography of large multi-acre campuses and the level of precision needed for a flood risk study. Vector (outlines) of the assets and site features would be necessary to determine actual flood risk exposure.

3) *Assumptions on shallow flooding may not reflect reality.* Agencies report vertical elevation on individual assets regarding the height of the tops of buildings. Per the MOBILE NOW Act, agencies report the height (or height range) of owned buildings and structures; the GIS COE appends that to the elevation at that location to derive a Building Height Above Mean Sea Level for each asset. To assess flood risk, data is needed on the vertical elevation of the structures and buildings in relation to soil conditions both at grade and below grade.

   Our assessment may assume that shallow flooding would lead to damages, which may not be true if the real property's vertical elevation is entirely above the grade. However, it also may underestimate risk as at- and below-grade conditions are complex building assemblies, which may or may not be resistant to flooding.

4) *The FRPP was not developed for or intended to be used as an asset management system or a source of data for complex analysis.* The FRPP is a once-a-year snapshot inventory system with generalized information on a limited set of data elements.

5) *While data collection is improving, data points such as longitude and latitude and other elements may not be as accurate as the Federal Government would like.* Errors or lack of precision in the data reported by departments and agencies could have a significant impact, since the analysis is dependent on the accuracy of information. Continuing the use of the longitude and latitude elements outlined above, within the public dataset 838 (0.27 percent) assets did not have a valid longitude and latitude and 3,347 (1.07 percent) assets are geocoded incorrectly (e.g., the longitude and latitude fell outside of the United States but other data elements in the Federal Real Property Profile identify the asset as being located within a State).[7] The overall accuracy of the location coordinates, when reported for individual assets, is unknown at this time. Within the public dataset, 2.3 percent of buildings and 0.7 percent of structures owned by the Federal Government were reported without a replacement value. Therefore, we report the count of exposed buildings and structures and the value of the exposed real property owned by the Federal Government, where possible.

6) *The estimated replacement values are uncertain, leading to a high degree of uncertainty in the loss estimate.* Agencies are directed to report to the FRPP the estimated replacement value, defined as the cost to rebuild the same asset according to today's standards. However, when there is a catastrophic event, many facilities are not replaced in kind regardless of the reason for their replacement. Given the opportunity to replace a facility, when agencies replace an asset, they do so in the most cost-effective manner and to gear toward current mission requirements, rather than the original purpose for which it was built. Other times, an agency may choose not to replace a facility at all and relocate the function. In addition, the estimated replacement values are sunk costs that are nonrecoverable and not considered in future decision-making, so these estimates are not appropriate for estimating financial loss to the Federal Government.

7) *The loss estimation is derived from Nofal and van de Lindt (2020) which utilizes commercial and residential property attributes that do not easily align to Federal facilities categories.* This presents issues because 1) building and structures owned by the Federal Government encompass a much broader set of categories than residential and commercial properties. Also, within the public dataset, 17,688 (17.6 percent) of buildings are classified as "All Other", which cannot be cross-walked to the archetypes specified in Nofal and van de Lindt (2020), and as such do not have a corresponding loss ratio and are dropped from the analysis. Separately, since the focus of this analysis is on buildings and structures, any damage that may be caused to land, such as soil erosion or losses of natural resources, or to critical underground infrastructure, such as utility conduit, is not included in loss estimates.

The analysis proceeds below with the above caveats noted.

[7] While replacement value is typically included within the FRPP public dataset, there are circumstances in which the replacement value is allowed to be excluded from the public dataset. Note exclusions are also possible for other real asset characteristics.

The assessment of flood risk to Federal facilities provided by the OMB white paper *Climate Risk Exposure: An Assessment of the Federal Government's Financial Risk to Climate Change* (Office of Management and Budget, 2022) supporting the 2023 President's Budget was conducted using the current flood hazard maps (FIRMS) from the Federal Emergency Management Agency (FEMA), along with data provided by the Sea Level Rise Viewer, which is produced by the National Oceanic and Atmospheric Administration (NOAA) (NOAA Office of Coastal Management, 2022). The analysis conducted for the 2024 President's Budget makes notable changes to incorporate recent advancements in projecting flood risks that reflect projections of climate change effects on fluvial, pluvial, and coastal flooding and inundation from sea level rise.

When considering the analysis using the fluvial, pluvial, and coastal flood projections described below and the analysis specifically examining inundation from SLR, the projections need to be considered separately and non-additively. The flood maps—which include fluvial, pluvial, and coastal flooding—provide exposure to flooding to inland and coastal areas (including impacts of SLR) for mid-century under a single climate change scenario. The separate SLR analysis allows us to examine the inundation from SLR mid- and late-century under different SLR scenarios; these SLR projections give additional perspective on the risk that the U.S. may face in the future.

Flood Risk Assessment—Projected Fluvial, Pluvial, and Coastal Flood Risk

For this year's assessment, flood hazards projected 30 years into the future are used rather than the current flood hazard maps from FEMA. With permission from the First Street Foundation, the assessment on flood hazards for the United States and U.S. territories was conducted by the U.S. Geological Survey (Wood et al. 2023), using projected flood-hazard zones from the First Street Foundation Flood Model (First Street Foundation, 2020). First Street Foundation Flood Model has a three-meter resolution. USGS aggregates flood-hazard zones of the First Street Foundation projected flood-hazard zones to a 30-meter resolution, which is the resolution of the hydraulic models underlying the First Street Foundation Flood Model.[8] These flood maps from First Street Foundation are projected to 30 years in the future under the Representative Concentration Pathway (RCP) 4.5 emissions scenario[9], which provides projected exposure for mid-century under a moderate radiative forcing scenario (Hayhoe et al., 2017). The First Street Foundation map products include current estimated flood depths and projected flood depths for 30 years in the future for 1) a 1 percent chance of being flooded in any given year (100-year floodplain) and 2) a 0.2 percent chance of being flooded in any given year (500-year floodplain). The flood hazards considered within the First Street Foundation Flood Model cover fluvial flooding, pluvial flooding, and coastal flooding.

In using the First Street Foundation modeling for the analysis in this paper, we want to highlight several notable differences between FEMA modeling for flood maps and the First Street Foundation modeling. The First Street modeling approach reduces precision throughout the modeling process to achieve the efficiency needed to create a national model. Then First Street includes several finishing steps to approximate a higher level of precision. FEMA's flood mapping

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[8] First Street uses high-resolution, geospatial elevation data and downscaling analytical methods to estimate the higher resolution 3-meter grids.

[9] The Representative Concentration Pathways, or RCPs, are widely used in the climate research community to describe different climate futures and are based on the volume of greenhouse gases emitted. RCPs form the foundation for the majority of recent climate-related modeling efforts.

achieves greater precision as FEMA modeling is created at the local level with data and reviews by local officials. The First Street Foundation data provide complete national coverage not available from FEMA, and includes a larger mapped area of flooding in the 100-year floodplain compared to FEMA's Special Flood Hazard Areas (First Street Foundation, June 29, 2020).[10]

For the analysis using the First Street Foundation Flood Model, projected annual losses are calculated in a manner similar to how Expected Annual Losses are calculated by FEMA as part of the National Risk Index product, in which

$$\text{Expected Replacement Value Effected by Flooding} = \text{Exposure} \times \text{Annualized Frequency} \times \text{Estimated Replacement Value Effected Ratio} \quad (1)$$

(Federal Emergency Management Agency, n.d.). *Exposure* is the total value of the asset at risk in a loss event. For this, the authors use the estimated replacement value from the FRPP dataset for each real property asset of the Federal Government, where reported. *Annualized Frequency* is the projected reoccurrence of the event. For instance, this would be the 1 percent annual probability associated with a Federal facility located in a 100-year flood hazard zone, or the 0.2 percent annual probability associated with a Federal facility in a 500-year flood hazard zone.[11] The *Estimated Replacement Value Effected Ratio* is the percent of the replacement value estimated to be effected by the event. For example, if the estimated replacement value of a Federally-owned office building is $5 million and the effect from a flood to the office building is estimated to be $1 million, the estimated replacement value effected ratio is equal to 20 percent ($1 million divided by $5 million).

Estimated replacement value effected ratios caused by flood inundation are adapted from Nofal and van de Lindt (2020), noting the ratios are relative to the replacement value for the entire building or structure. In this method, building-scale component-based flood fragilities are developed for a suite of 15 building archetypes for a community-scale building portfolio (see Table A.2 for a list of the archetypes). Building component flood fragilities represent the flood depth at which common components of buildings are damaged for multiple damage states (or levels of building performance). Associated functions representing the weighted estimated replacement value of each building's component for the damage states are presented for each building archetype (*ibid*.). The application of the Nofal and van de Lindt (2020) fragility-based loss functions in this analysis requires the allocation of FRPP MS building categories to the Nofal and van de Lindt building archetypes and use of the corresponding building flood depths (based on results from the First Street Foundation Flood Model).

[10] First Street's current conditions 100-year floodplain includes flooding that is not included in the definition of the Special Flood Hazard Areas shown on FEMA maps. This additional flooding includes very shallow flooding and flooding not associated with the primary stream network that FEMA analyzes.
FEMA shows some of these flood hazards in the shaded X zone (combined with the 500-year floodplain areas) but not in the SFHA. FEMA generally does not analyze shallow flooding caused by directly by heavy rainfall (as opposed to rainfall that results in overflow from rivers and lakes), i.e. "pluvial" flooding.

[11] Note the 100-year hazard zone is a subset of the 500-year hazard zone within the First Street Foundation Flood Model. This differs from the flood hazard maps of FEMA where the "500-year flood hazard zone" are for areas that have an annual probability of significant flooding greater than or equal 0.2 percent but less than 1 percent.

The building archetypes developed by Nofal and van de Lindt (2020) do not perfectly correspond with the "Real Property Uses" within the FRPP, given the archetypes were developed with general building types of communities in mind, rather than archetypes of Federal real property assets. Therefore, the "Real Property Uses" of the FRPP are matched as best as possible to the archetypes of Nofal and van de Lindt (2020). See the appendix (Table A.3) for details of this mapping. As mentioned in the caveats above, within the FRPP public dataset, 17,688 (17.6 percent) of buildings are classified as "All Other", which cannot be cross-walked to the archetypes specified in Nofal and van de Lindt (2020), and as such do not have a corresponding loss ratio and are dropped from the analysis.

Additionally, since the archetypes of Nofal and van de Lindt (2020) are only for buildings, the projected estimated replacement values effected are only reported for buildings, while *exposure* (i.e., total replacement value) is reported for buildings and structures, with the exception of structures classified as "Navigation and Traffic Aids (other than buildings)." This exception is because not all navigation aids, such as buoys and channel markets, are located on land. Effects to horizontal infrastructure (e.g., roads, airfields, railroads, levees, dikes) may not be adequately accounted for in this method.

The paper reports both projected exposure and projected estimated replacement value effected from flooding. Because of the updated method presented in this assessment, the exposure presented here differs substantially from the results presented in last year's (2023 President's Budget) assessment on the flood risk to Federal facilities. This assessment's exposed value of Federal facilities for the year 2022 within the 100-year floodplain (1 percent annual chance of flooding) is more than double when using the modeling from First Street Foundation relative to the analysis performed for the 2023 President's Budget using the FEMA Flood Maps. This large difference in estimated Federal facility exposure when using FEMA or First Street Foundation models highlights the complexity of this work and how variations in modeling can lead to notable changes in exposure estimates.

Table 12 shows real property owned by the Federal Government included in the public FRPP dataset projected to be exposed in a 100-year or 500-year floodplain, according to the First Street Foundation Model. For buildings, of the 100,540 federally-owned buildings included in the public dataset, the First Street Foundation Flood Model estimates that currently over 24,000 buildings (24%) owned by the Federal Government are currently within a 100-year floodplain and an additional approximately 30,000 are within a 500-year floodplain. Assuming that Federal buildings and structures remain in their current sites and not accounting for newly built facilities over the next 30 years, the percent of buildings in the expanded floodplain in the 2052 100-year floodplain is projected 3 percent greater than the 2032 100-year floodplain. This is the same percentage increase for buildings in the 500-year floodplain between 2032 and 2052. For structures, the First Street Foundation Flood Model estimates that currently approximately 48,000 federally-owned structures are in the 100-year floodplain, which is projected to increase over 2 percent, by 2052. Structures within the 500-year floodplain are projected to increase slightly less than 2 percent, by 2052.

TABLE 12: TEST CASE NUMERIC RESULTS COUNT OF FEDERALLY-OWNED REAL PROPERTY ASSETS IN THE PUBLIC FRPP DATASET CURRENTLY EXPOSED TO FLOOD HAZARDS AND PROJECTED EXPOSURE IN 2052, BASED ON THE FIRST STREET FOUNDATION FLOOD MODEL.
[NOT OFFICIAL GOVERNMENT ESTIMATES]

Scenario and Time Period	Exposed Buildings	Exposed Structures
100-year Flood Exposure: 2022 (exploratory; not for decision-making)	24,295	47,693
100-year Flood Exposure: 2052 (exploratory; not for decision-making)	25,072	48,839
500-year Flood Exposure: 2022(exploratory; not for decision-making)	29,869	54,906
500-year Flood Exposure: 2052 (exploratory; not for decision-making)	30,816	55,856

Note: Analysis is an illustrative example of the process for developing projections, rather than an official Government estimate of the projected losses. These projections are not for decision-making purposes. See caveats on FRPP MS data pgs. 11-12. Precision shown to single digit for illustrative purposes only.

Based on this analysis, the number of buildings and the aggregate estimated replacement value of federally-owned real property in the public dataset exposed to flooding is projected to increase over time as the number of exposed assets increases (see Table 3). Current building exposure is estimated at $59 billion estimated replacement value within the 100-year floodplain and $76 billion estimated replacement value for the 500-year floodplain, with the exposed estimated replacement value effected anticipated to increase by $4 billion for buildings in the 100-year floodplain and $6 billion estimated replacement value in the 500-year floodplain. Current exposure for structure estimated replacement value is at $131 billion and $160 billion estimated replacement value for the 100-year and 500-year floodplains, respectively, which are anticipated to have respective increases of $5 billion estimated replacement value and $2 billion estimated replacement value by 2052. The analysis should be construed as an illustrative example of the process for developing projections, rather than an official Government estimate of the projected losses, because of the underestimation of climate financial risk due to tool limitations. These exposure figures should also be interpreted carefully as a large exposed replacement value does not necessarily translate to large losses. The function of the building or structure is key to determining the percentage of exposed value that may be determined to be damaged and lost.

TABLE 3: TEST CASE NUMERIC RESULTS: EXPOSED ESTIMATED REPLACEMENT VALUE EXPOSED BY SCENARIO AND TIME PERIOD
(in billions of dollars)[a]
[NOT OFFICIAL GOVERNMENT RESULTS]

Scenario and Time Period	Building	Structure
100-year Flood Exposure: 2022 (exploratory; not for decision-making)	$58.5	$131.4
100-year Flood Exposure: 2052(exploratory; not for decision-making)	$62.3	$136.4
500-year Flood Exposure: 2022(exploratory; not for decision-making)	$75.6	$159.7
500-year Flood Exposure: 2052(exploratory; not for decision-making)	$81.4	$161.2
Total Replacement Value[b] (exploratory; not for decision-making)	**$399.9**	**$439.8**

[a] Analysis is an illustrative example of the process for developing projections, rather than an official Government estimate of the projected losses. These projections are not for decision-making purposes. Estimated replacement value is not a financial loss to the Federal Government. See caveats on FRPP MS data pgs. 11-12.

[b] The total replacement value reflects replacement value where available, regardless of whether the building or structure is within a 100 year or 500 year floodplain. Within the public dataset 2.3 percent of buildings and 0.7 percent of structures owned by the Federal government are reported without a replacement value.

Table 4 illustrates the numeric results of the test case, showing the projected estimated replacement value effected by flooding for Federal buildings from flooding (calculated using equation (1)). Ranges of estimated replacement value effected by flooding are provided, given the uncertainty in the projected flood depths, with a greater effect on estimated replacement value being associated with higher flood depths. The effect on annual estimated replacement value for a 100-year flood event is projected to increase between $10 million to $39 million by 2052. For a 500-year flood event, the effect on annual estimated replacement value is projected to increase $2 million to $5 million. The overall projected effect on estimated replacement value is smaller for a 500-year flood event relative to the effect on estimated replacement value under the 100-year flood event, since the lower probability of the 500-year flood event (0.2 percent) more than offsets the greater severity and area covered of the 500-year flood relative to the 100-year flood. These figures do not represent official government estimates and should not be used for decision-making purposes.

TABLE 4: TEST CASE NUMERIC RESULTS: PROJECTED ANNUAL ESTIMATED REPLACEMENT VALUE EFFECTED BY FLOODING
(in millions of dollars)
[NOT OFFICIAL GOVERNMENT RESULTS]

	100-year Flood (1% annual chance)			500-year Flood (0.2% annual chance)		
	Year 2022	Year 2052	**Change: 2022 to 2052**	Year 2022	Year 2052	**Change: 2022 to 2052**
Low (exploratory; not for decision-making)	$84	$94	**$10**	$23	$24	**$2**
Midpoint (exploratory; not for decision-making)	$171	$195	**$25**	$46	$49	**$3**
High (exploratory; not for decision-making)	$258	$297	**$39**	$70	$74	**$5**

Note: Analysis is an illustrative example of the process for developing projections, rather than an official Government estimate of the projected losses. These projections are not for decision-making purposes. Estimated replacement value effected is not a financial loss to the Federal government. See caveats on FRPP MS data pgs. 11-12.

Limitations and Caveats on the Modeling of Projected Fluvial, Pluvial, and Coastal Flooding

First Street Foundation data are widely available and provide projections for flood hazards that incorporate climate change assumptions. Work in this area is rapidly evolving; therefore, allowing for flexibility in updating the methodology is key to reducing uncertainty and possible bias in the projections. As work in this area continues, the projected exposure and level of uncertainty in the projections in flood risk will change. Limitations for this work include but are not limited to:

- The First Street Foundation Flood Model only provides projections only for the RCP 4.5 scenario and for the next 30 years. Relative to other assessments, such as the wildland fire assessment from last year, this scenario and time period produce a lower estimated increase in risk relative to projections using the RCP 8.5 scenario or the late-century time period (Office of Management and Budget, 2022). The observed increase in global carbon emissions over the past 15–20 years has been consistently higher than the RCP 4.5 emissions scenario (with very high confidence) (Hayhoe et. al., 2018). Therefore, the RCP 4.5 emissions scenario represents a lower bound (Avery et. al, 2018).
- The First Street Foundation Flood Model uses data on the frequency of precipitation to inform the modeling of pluvial flood risks. While NOAA's Atlas-14 dataset is a peer-reviewed data source on precipitation frequency, Atlas-14 is currently undergoing updating using funds from the Infrastructure Investment and Jobs Act (P.L. 117–58). Given the vintage of the Atlas-14 dataset, pluvial flood risk may be underreported in certain locations. The precipitation frequencies that result from the Atlas-14 update may differ from those currently used in the First Street Foundation Flood Model. In particular, the authors expect that future datasets will reflect new characterizations of non-coastal flood risk.
- The First Street Foundation Flood Model uses published models of future climate impacts to create estimates of future flood conditions. There is substantial variation across these models at the regional and national scales they were originally developed at. Downscaling

model results to produce local-scale estimates of future flood risk results in much greater uncertainty. Additionally, there is limited consensus for estimates of future precipitation and storm intensity at the high spatial resolution needed for characterizing and assessing future local flood risk. Data, such as the projections from the First Street Foundation Flood Model, provide a useful scenario for planning, but users should be aware of the large uncertainties and consider multiple possible future scenarios for local decision making.

- The First Street Foundation modeling approach reduces precision throughout the modeling process to achieve the efficiency needed to create a national model. First Street Foundation includes several finishing steps that attempt to approximate a higher level of precision, but should not be considered a substitute for flood modeling informed by local level data and reviews by local officials.
- Areas with ungauged catchments—that is, locations where water collects, particularly from rainfall—cannot be accurately projected within the modeling (First Street Foundation, 2020).
- The resolution of projections produced by GeoClaw (software that "simulates shallow-water flow")[12] (George, 2022) may not adequately capture the flood risk associated with narrow passages of water, such as canals (First Street Foundation, 2020).
- Digital Elevation Models (DEMs) are critical to estimating flood hazards, and older, less accurate DEMs can lead to mischaracterization of flood risk, noting some areas have not recently had DEMs updated with the most recent technology.
- Further limitations exist in the ability to account for climate adaptation and flood control measures, which can either contribute to under- or over-estimating the projected flood hazards.

Flood Risk Assessment—Sea Level Rise

This year's assessment uses SLR projections released by the Sea Level Rise and Coastal Flood Hazard and Tools Interagency Task Force in 2022. The NOAA Office for Coastal Management evaluated the intersection between locations of the Federal Real Property Profile and areas of projected inundation from SLR. In order to accomplish this analysis, the NOAA Office of Coastal Management used the *NOAA Digital Coast Sea Level Rise 1-10ft* data, [13] which underlie the Sea Level Rise Viewer (NOAA Office of Coastal Management, 2022), and the *Global and Regional Sea Level Rise Scenarios for the United States*[14] (Sweet et. al, 2022). The NOAA Digital Coast data represent potential inundation from SLR in one-foot increments above Mean Higher High Water (MHHW) (NOAA Office of Coastal Management, 2022). As defined by NOAA, Mean Higher High Water is "The average of the higher high water height of each tidal day observed over the National Tidal Datum Epoch," where the National Tidal Datum Epoch is a 19-year period for

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[12] George, D.L. (2022). "GeoClaw: software for simulating shallow-water flows." https://dlgeorge.github.io/project/geoclaw-project

[13] NOAA's Digital Coast Sea Level Rise Viewer can be found here https://coast.noaa.gov/digitalcoast/tools/slr.html and the underlying data downloaded here: https://coast.noaa.gov/slrdata. Further information on the mapping methods can be located at this site, https://coast.noaa.gov/data/digitalcoast/pdf/slr-inundation-methods.pdf, with metadata available at https://www.fisheries.noaa.gov/inport/item/48106.

[14] The site Interagency Sea Level Rise Scenario Tool – NASA Sea Level Change Portal provides an interactive tool with the projections developed by Sweet and colleagues (2002).

collecting data on water level measures, such as mean sea level, high water, and low high water (also known as tidal datum) (NOAA Tides and Current, n.d.).

The Digital Coast data allow an analyst to determine an approximate threshold of projected SLR that would result in inundating Federal real property. The data from *Global and Regional Sea Level Rise Scenarios* for the United States provide projections of mean SLR under different climate change scenarios and time periods (Sweet et al., 2022). For a specific location, if the SLR projected by Sweet and colleagues (2022) exceeds the Digital Coast Sea Level Rise data, then that location would be inundated. For example, suppose the Digital Coast Sea Level Rise data show that a Federal facility would be inundated if SLR reached 3 feet at the location of the facility. If the data from *Global and Regional Sea Level Rise Scenarios* show that under a particular scenario (e.g., the Intermediate High scenario) that SLR will be greater than 3 feet, then the facility would be inundated under the Intermediate High Scenario. If SLR in the Intermediate High scenario is less than 3 feet, the property would not be inundated. The one-degree resolution gridded SLR scenarios data (NOAA, 2022) were used to determine each Federal real property's SLR projection for the years 2050 and 2100 for the Intermediate and Intermediate-High scenarios presented in the *Global and Regional Sea Level Rise Scenarios* (Sweet et al., 2022).

The report provides projections for five sea level scenarios resulting in the following Global Mean Sea Level changes, relative to a year 2000 baseline, in 2100: Low (0.3 meters), Intermediate-Low (0.5 meters), Intermediate (1 meter), Intermediate-High (1.5 meters), and High (2 meters). We choose the Intermediate and Intermediate High scenarios for this analysis, which represent potential and likely upper bound scenarios. Under high global greenhouse gas emissions (RCP 8.5), the likelihood of exceeding one meter of SLR by 2100 is at least 23 percent (Sweet et. al, 2022); accordingly, the selected scenarios represent a possible range of risks that Federal facilities may face.

At the point a building or structure is inundated by the MHHW level, the building's operations will continually be impacted by SLR. Tides reach the MHHW level repeatedly throughout the year, hence the annual probability of reaching MHHW is assumed to be 1. This differs from the First Street Foundation Flood Model, where the projected floods have low annual probabilities. As such, the expected loss for SLR flooding has been updated in equation (2) by removing the annual probability from equation (1) since the probability is equal to 1 within this SLR analysis.

$$\text{Expected replacement value effected for SLR} = \text{Flood Exposure} \times \text{Estimated Replacement Value Effect Ratio} \quad (2)$$

For equation (2), like equation (1), the estimated replacement value effected ratio is calculated using the loss estimation adapted from Nofal and van de Lindt (2020). Fewer real property assets owned by the Federal Government are estimated to be impacted by routine tidal flooding caused by SLR using the projections from *Global and Regional Sea Level Rise Scenarios for the United States* (Sweet et. al, 2022), compared to the number of assets included in 100-year or 500-year floodplains (see Table 5), due to fewer real properties being exposed to SLR relative to the number of properties exposed to flooding projected by the First Street Foundation Model. Under the Intermediate and Intermediate High Scenarios of SLR, less than 300 buildings and approximately 1,400 structures are estimated to be inundated by 2050. While the number of assets impacted for both scenarios by 2050 are similar, the projected inundation under the two scenarios deviates by 2100, with the number of inundated buildings increasing to almost 800 buildings under the Intermediate SLR scenario and over 1,700 buildings under the Intermediate High SLR scenario. For structures, the number inundated increases to over 3,200 structures under the Intermediate SLR scenario and almost 5,100 structures under the Intermediate High SLR scenario.

TABLE 5: TEST CASE NUMERIC RESULTS COUNT OF FEDERALLY-OWNED REAL PROPERTY ASSETS IN THE PUBLIC FRPP DATASET PROJECTED TO BE INUNDATED BY SLR
[NOT OFFICIAL GOVERNMENT ESTIMATES]

Scenario: Time Period	Buildings	Structures
Intermediate: 2050 (exploratory; not for decision-making)	257	1,378
Intermediate: 2100 (exploratory; not for decision-making)	793	3,236
Intermediate High: 2050 (exploratory; not for decision-making)	264	1,421
Intermediate High: 2100 (exploratory; not for decision-making)	1,752	5,077

Note: Analysis is an illustrative example of the process for developing projections, rather than an official Government estimate of the projected losses. These projections are not for decision-making purposes. See caveats on FRPP MS data pgs. 11-12. Precision shown to single digit for illustrative purposes only.

For the SLR scenarios (Table 6), the exposed estimated replacement value effected for buildings is projected to increase by $400 million between 2050 and 2100 under the Intermediate SLR scenario and increase by $4.7 billion under the Intermediate High SLR scenario for the same time periods. Relative to buildings, the increase in exposed estimated replacement value of structures is projected to be larger with an increase of $4.5 billion between 2050 and 2100 for the Intermediate SLR scenario and an increase of $8.3 billion for the Intermediate High scenario.

TABLE 6: TEST CASE NUMBERIC RESULTS EXPOSED ESTIMATED REPLACEMENT VALUE EFFECTED BY SCENARIO AND TIME PERIOD
(in billions of dollars)
[NOT OFFICIAL GOVERNMENT RESULTS]

Scenario and Time Period	**Building**	**Structure**
SLR Intermediate: 2050 (exploratory; not for decision-making)	$0.7	$5.0
SLR Intermediate: 2100 (exploratory; not for decision-making)	$1.1	$9.5
SLR Intermediate High: 2050 (exploratory; not for decision-making)	$0.7	$5.3
SLR Intermediate High: 2100 (exploratory; not for decision-making)	$5.8	$17.8

Note: Analysis is an illustrative example of the process for developing projections, rather than an official Government estimate of the projected losses. See caveats on FRPP MS data pgs. 11-12. These projections are not for decision-making purposes.

The estimated replacement value effected from SLR is projected between $72 million and $127 million for mid-century and between $449 million and $1.786 billion by the end of the century (see Table 7, calculated using equation (2)), noting these losses are projected under SLR scenarios that are not comparable to the climate change scenario that underlie the projections for the 100-year and 500-year floodplains in 2052.

TABLE 7: TEST CASE NUMBERIC RESULTS:
ESTIMATED REPLACEMENT VALUE EFFECTED FROM SLR
(in millions of dollars)
[NOT OFFICIAL GOVERNMENT ESTIMATES]

Scenario	**Year**	**Projected Loss**
Intermediate (exploratory; not for decision-making)	2050	$72
	2100	$449
Intermediate High (exploratory; not for decision-making)	2050	$127
	2100	$1,786

Note: Analysis is an illustrative example of the process for developing projections, rather than an official Government estimate of the projected losses. These projections are not for decision-making purposes. Estimated replacement value effected is not a financial loss to the Federal government. See caveats on FRPP MS data pgs. 11-12.

Limitations and Caveats on the Modeling of Sea Level Rise

When considering the projected flooding from SLR, there are several caveats.

- The Digital Coast data were not designed for location-specific analysis, which NOAA explicitly states in the disclaimer of the Sea Level Rise Viewer (NOAA Office of Coastal Management, n.d.).
- This analysis does not account for multiple factors critical to determining coastal flood risk. These risks are highlighted in *Global and Regional Sea Level Rise Scenarios for the United States* (Sweet et. al, 2022) and include storm surge, rainfall, and changes in the coastal water table. The analysis does not account for changes outside of SLR that will affect coastal inundation, such as soil erosion, subsidence (i.e., sinking of land), future construction, or future changes in geomorphology. Additionally, this analysis does not include details that would be present in an engineering hydrologic analysis (e.g., dikes, culverts) (*ibid.*).
- Like the analysis conducted using the First Street Foundation projections, climate adaptation measures cannot adequately be incorporated into the analysis at this time.
- These projections of SLR do not include Alaska due to the lack of high-resolution elevation data.[15] Within the public dataset, 2.3 percent of the buildings and 2.4 percent of the structures are in Alaska.

Conclusions

[15] For more information, see the Frequently Asked Questions at https://coast.noaa.gov/data/digitalcoast/pdf/slr-faq.pdf. Additionally, No Data Areas available at ftp://ftp.coast.noaa.gov/pub/hazards/SLRViewer/NOAA_SLR_Viewer_NoDataAreas.zip

While the flood risks to Federal assets and communities are evolving over time due to climate change, the projections presented here need to be taken as preliminary and partial. As the science evolves, projections of exposure and loss are likely to change. The data on Federal assets, the mapping of current and projected fluvial and pluvial flood hazards, and application of the loss factor all come with notable caveats, strong assumptions, and limitations. These uncertainties can be amplified, either increasing or decreasing the flood risk in the results. The purpose of this assessment is to provide transparency into the current abilities to evaluate climate risks and highlight areas for improvement.

Part of the ongoing work in this area is to advance the implementation of Executive Orders 11988, "Floodplain Management" (1977); E.O. 13690, "Establishing a Federal Flood Risk Management Standard and a Process for Further Soliciting and Considering Stakeholder Input" (2015);[16] and the Federal Flood Risk Management Standard (FFRMS). E.O. 13690, which establishes a FFRMS to ensure agencies take actions to enhance the Nation's resilience to current and future flooding. E.O. 13690 and the associated FFRMS amended and built upon E.O. 11988 on *Floodplain Management* (1977), which requires agencies to take action to reduce the risk of flood loss, to minimize the impact of floods on human safety, health and welfare, and to restore and preserve the natural and beneficial values served by floodplains.

[16] E.O. 14030, "Climate-related Financial Risk", reinstated E.O. 13690.

Projected Impacts of Higher Temperatures on the Low Income Home Energy Assistance Program

The Fourth National Climate Assessment (NCA4) examines the impacts of extreme heat on human health (Ebi et. al, 2018). Extreme heat is tied to higher risks for multiple illnesses and death, especially for vulnerable populations, such as older adults, children, and pregnant women. Urban heat islands—urban areas with higher temperatures, related to nature cover replaced with pavement, buildings, and man-made structures that absorb and retain heat—further worsen the risk for heat-related illnesses. Heat-related illnesses include cardiovascular and respiratory complications (Ross et. al, 2018), electrolyte imbalance, kidney stones (Gronlund et. al, 2016), and premature birth (Ha et. al, 2017). Although cold-related deaths are projected to decline due to climate change, the projections of heat-related deaths far exceed the decline in cold-related deaths (Sarofim et. al, 2016). These projected impacts highlight the importance of Federal programs that help mitigate the risks of temperature-related illnesses and deaths, such as the Low Income Home Energy Assistance Program (LIHEAP). [17]

LIHEAP provides households with financial assistance to offset energy costs. LIHEAP benefits target households with low incomes, particularly those that have a high home energy burden (percentage of income that goes to heating and cooling bills). LIHEAP also targets households that have members who are older adults, have disabilities, or young children (Administration for Children and Families, n.d.a). States, territories, tribes, and tribal organizations are eligible to apply for grants under LIHEAP. Grant recipients then distribute the benefits to households, noting that all 50 States, the District of Columbia, all five territories and over 150 tribes are grant recipients. As a block grant program, LIHEAP grant recipients have flexibility in designing and implementing program components to distribute LIHEAP benefits to eligible households. While income eligibility for LIHEAP is determined by the grant recipient, the statutory limits for household income are (1) no greater than 150 percent of the Federal Poverty Guidelines (FPG) or 60 percent of the State Median Income, and (2) no less than 110 percent of FPG.

The majority of funding for LIHEAP is awarded through block grant annual appropriations. The block grant allocation to States in FY2021 was $3.649 billion, serving approximately 5.4 million households (Administration for Children and Families, n.d.b). Approximately 15 percent of the estimated income-eligible population was served by any type of assistance under LIHEAP in Fiscal Year 2021 (*ibid.*). In 2020 and 2021, LIHEAP received supplemental funding from the CARES Act (P.L. 116-136) and the American Rescue Plan Act (P.L. 117–2), respectively. The $900 million provided by the CARES Act provided grant recipients with additional funds to assisted households during the coronavirus pandemic. In particular, this funding was beneficial to households impacted by the pandemic and income loss by paying utility arrearage balances prior to or as disconnection moratoriums set by States expired in 2020 or 2021, depending on the State (National Association of Regulatory Utility Commissions, 2021)., [18] The American Rescue Plan Act (ARPA) provided an additional $4.5 billion in funding. These supplemental funds were used

[17] 42 U.S.C. 8621 et seq.

[18] Grant recipients were also able to use these funds for any purpose normally authorized under the federal LIHEAP statute (42 USC 8621 et seq.), including heating, cooling, crisis, weatherization assistance, case management for the reduction of home energy burden, and administrative costs.

for a variety of purposes, such as beginning new cooling assistance programs, broadening eligibility requirements to serve more households, paying off arrearages, purchasing/repairing home energy equipment, and supplementing current assistance with increased benefit levels.
The majority of funding for LIHEAP goes towards assisting households with the cost of home energy bills[19]. In FY2021—the most recent data available—$2.877 billion in heating assistance went to 4.460 million households and $564 million in cooling assistance went to 766,000 households. All States offered heating assistance in 2021, while only 24 States offered cooling assistance. Kentucky and Rhode Island both added cooling assistance programs in FY2020, and Utah added one in FY2021. The FY2021 assistance does include supplemental funding. In FY2019—the most recent year with no supplemental funding—total benefits for heating assistance equaled $1.742 billion and total cooling benefits equaled $326 million (Administration for Children and Families, n.d.b). Crisis assistance can be for "winter", "summer", and "year round". The definition of a crisis varies by State, but generally the assistance is provided if there is a disconnection, loss of energy service, or imminent risk of disconnection of heating or cooling (Administration for Children and Families, n.d.c). In FY2021, $1.272 billion was provided for crisis support, and in FY2019 $722 million was provided (Administration for Children and Families, n.d.b).

The LIHEAP Data Warehouse provides national and State-level data by fiscal year and grantee for a variety of measures within the program, including funding sources available, how funds were designated and used, the estimated income-eligible population, the number of LIHEAP recipient households, and the average annual benefits (Administration for Children and Families, n.d.b). Table 8 shows the inflation-adjusted average benefits per household by type of assistance for the grantees within the continental United States (CONUS). Years when grantees average $0 in benefits per household—i.e., the grantee did not administer that form of assistance for that year—are not included. The wide range of average benefits is the result of geographic/climatic differences and variations in the implementation of the grants across grantees.

[19] In FY2021, $516 million of the benefits under LIHEAP went to payments for weatherization.

TABLE 8: SUMMARY OF HISTORICAL AVERAGE BENEFITS ACROSS GRANT RECIPIENTS, ADJUSTED FOR INFLATION (2021$)

	Heating	Cooling	Winter Crisis	Year Round Crisis[a]	Summer Crisis
Minimum	$46	$57	$25	$43	$12
25th Percentile	$325	$203	$317	$307	$216
Median	$464	$316	$417	$423	$286
75th Percentile	$648	$501	$517	$533	$403
Maximum	$3,230	$2,128	$1,615	$4,301	$1,023

[a] Year Round Crisis can be used for winter or summer crises. The benefits are combined here since they are combined within the LIHEAP Datawarehouse.

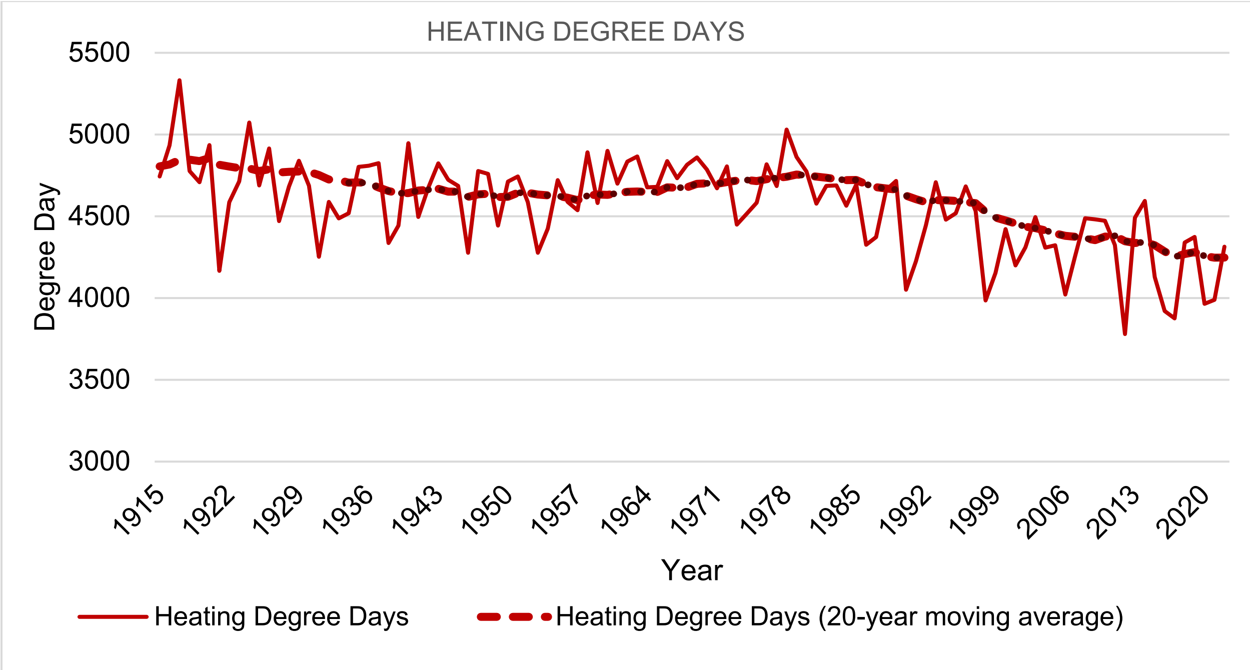
Risks from Increasing Temperatures

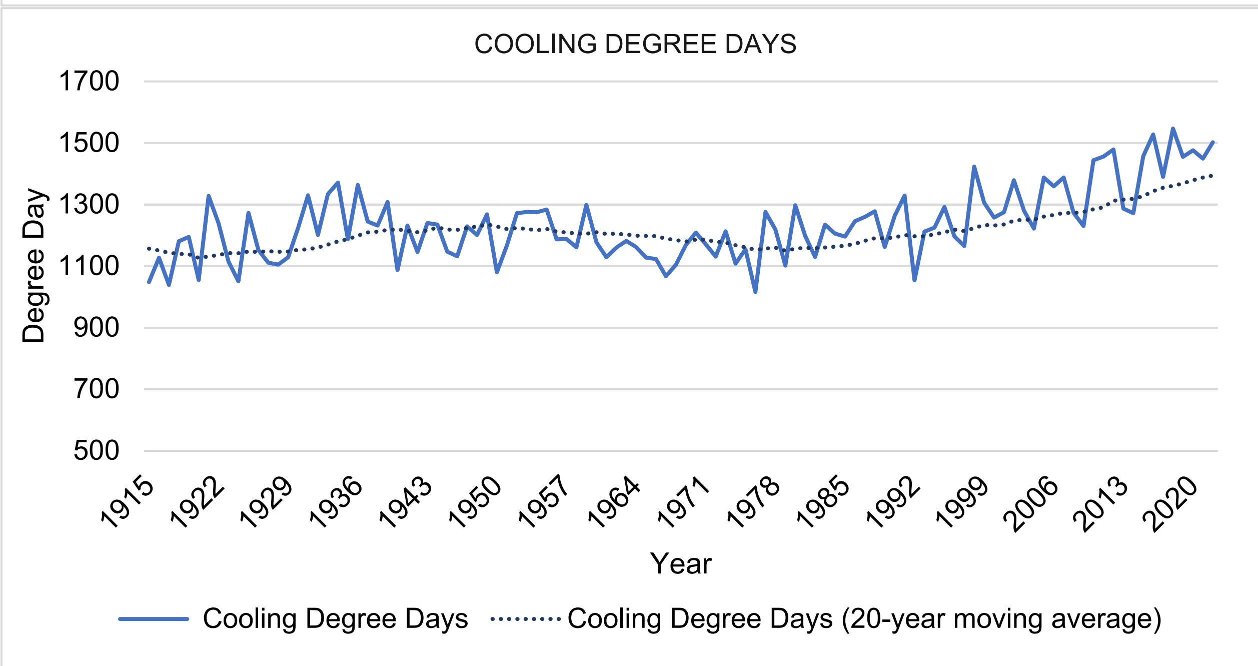
Figure 1 highlights how heating degree days and cooling degree days have changed over the last century for the continental United States (CONUS).[20] Degree days are measures of how cold or warm a location is. A degree day compares the mean (the average of the high and low) outdoor temperatures recorded for a location to a standard temperature, usually 65º Fahrenheit. The more extreme the outside temperature, the higher the number of degree days. A high number of degree days generally results in higher levels of energy use for space heating or cooling (Energy Information Administration, n.d.). When examining the 20-year moving averages for cooling degree days and heating degree days for the years 1915 versus 2022[21], cooling degree days have already increased in the United States by 20 percent, while heating degree days have decreased 12 percent. These trends indicate that energy demand for cooling is likely to continue increasing, while energy demand for heating will decline.

[20] National Centers for Environmental Information, National Oceanic Atmospheric Administration, 2022. Climate at a Glance National Time Series. https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/national/time-series/

[21] The years included in the moving averages are (1896-1915) for 1915 and (2003-2022) for 2022.

FIGURE 1: HEATING DEGREE DAYS AND COOLING DEGREE DAYS FOR THE CONTINENTAL UNITED STATES, FOR THE YEARS 1915 – 2022[a]





[a] Heating degree days are equal to the annual sum of the greater of 1) 65 degrees Fahrenheit minus the daily average temperature or 2) zero. Cooling degree days are equal to the annual sum of the greater of 1) the daily average temperature minus 65 degrees Fahrenheit or 2) zero.

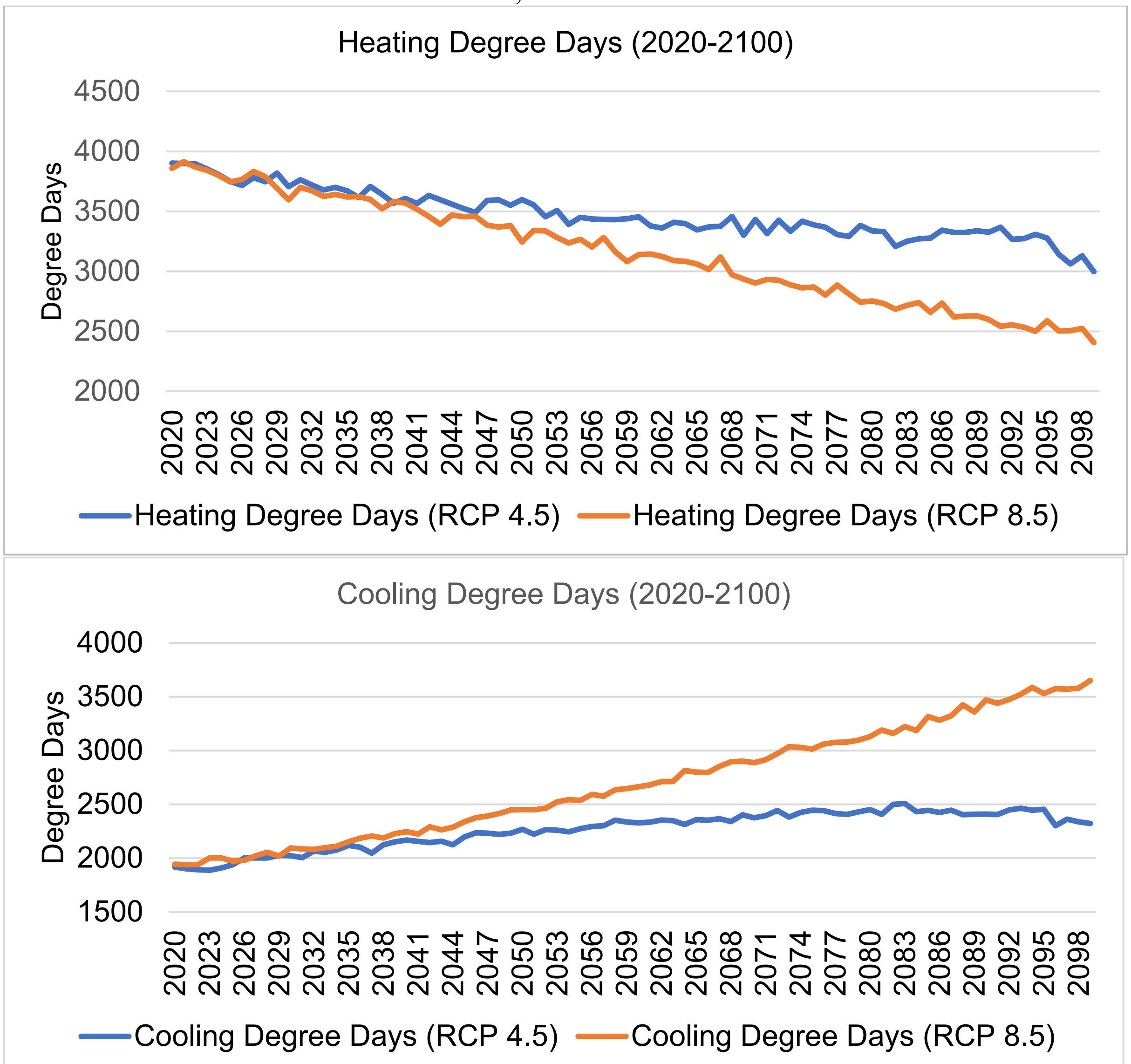
Source: National Centers for Environmental Information, National Oceanic Atmospheric Administration, 2022.

Larsen and colleagues (2017) conducted a forward-looking assessment on the impact of rising temperatures on the U.S. power sector, providing projections on the change in cooling degree days, extreme heat, and energy demand through 2040. Under a very high emissions scenario (RCP8.5), most of the South and many parts of the Southwest can expect to see an increase of at least 600 cooling degree days a year by 2040. Nearly a fifth of U.S. counties can expect to see the number of cooling degree days jump by 50% or more by 2040 (under a median RCP8.5 outcome). Even with more modest temperature changes under RCP2.6, most U.S. counties will likely face a rise in cooling degree days of between 200 and 500 a year by 2040 (*ibid.*). By 2040, much of the continental U.S. is projected to experience warmer summers and a rise in the number of extreme-heat days (those with maximum temperatures over 95º F). The average American has historically experienced around fourteen days over 95º F each year. With climate change under a high emissions scenario (RCP 8.5) in 2040, that same person will *likely* (67% probability) experience three to six weeks (25-40 days) of extreme heat each year on average. Much of Texas and the West South Central region can expect to experience two to three months of these extreme-heat days every year (*ibid.*). As a result, national residential and commercial electricity demand is projected to rise due to increased demand for space cooling. With a very high emissions scenario (RCP8.5), residential and commercial electricity demand will *likely* rise 3-9% above levels expected if historical climate conditions were to continue through 2040. Even under a low greenhouse gas emissions pathway (RCP2.6), additional warming will likely increase residential and commercial electricity demand 2-7% nationwide by 2040 (*ibid.*).

Consistent with the findings of Larsen and colleagues (2017), this assessment projects an increase of cooling degree days and decrease of heating degree days to continue under different warming scenarios, as shown in Figure 2. Under the RCP 4.5 emissions scenario, the 20-year average for heating days is projected to decline by 13 percent between 2039[22] and 2099[23], while the number of cooling degree days increases by 20 percent for the same time period. For the RCP 8.5 emissions scenario, heating degree days are projected to decline by 30 percent, while cooling degree days are projected to increase by 65 percent. These trends may impact energy demand for heating and cooling, and in turn, the needs of LIHEAP. In addition to changes in the trends of cooling degree days and heating degree days, extreme weather events induced by climate change will continue to impact the needs of cooling and heating assistance, as the frequency, duration, and intensity of extreme weather events are projected to change over time.

[22] 20 year average uses the years 2020-2039.
[23] 20 year average uses the years 2070-2099.

FIGURE 2: PROJECTED HEATING DEGREE DAYS AND COOLING DEGREE DAYS FOR THE CONTINENTAL UNITED STATES, 2020– 2100[A]



[a] Heating degree days are equal to the annual sum of the greater of 1) 65 degrees Fahrenheit minus the daily average temperature or 2) zero. Cooling degree days are equal to the annual sum of the greater of 1) the daily average temperature minus 65 degrees Fahrenheit or 2) zero.
Source: Coupled Model Intercomparison Project 5 (CMIP5), author's calculations

Conclusions

In order to develop expenditure projections of LIHEAP that could be used within decision-making, there are several areas of research that would need to be further developed:

1. Underpin all perils risk with the most up to date climate modeling relying on expertise from NOAA, the National Labs and industry experts,
2. Incorporate modeling on the costs of natural gas and other residential energy sources used for residential heating, and the transition to electrification,

3. Integrate grantees' design decisions into modelling,
4. Incorporate assumptions regarding population growth and interstate migration, and
5. Analyze electrical grid stability to understand the ability of the current framework of utility distribution to handle increased demand for cooling.

While other aspects of the modeling could also be further developed, these items are essential to developing informative projections.

Establishing a Common Framework for Evaluating Climate-related Financial Risks

Examining the Federal Government's climate risk exposure provides critical information on the vulnerabilities and strengths of the Federal Government's programs and assets, and the impact on the missions of Federal agencies. Although this analysis underestimates climate risk, due to the limitations of currently available tools to evaluate multiple forms of exposure to climate risk, it shows the importance of providing policymakers and stakeholders a framework for the potential monetary impacts of climate change on Federal assets and programs. Furthermore, this analysis of climate change on the Federal Budget reveals the limitations of current tools when evaluating the vulnerabilities of Federal programs.

Meeting the requirements of Section 6(b) of E.O. 14030, "Climate-related Financial Risks" in future years requires a consistent and repeatable methodology to enable year-over-year comparisons, inform action to reduce climate-related financial risk to the Federal Budget, and improve understanding of the effect of actions agencies are taking to reduce these risks. To address this challenge, the White House established the Assessments of Federal Financial Climate Risk Interagency Working Group (AFFCR), which is led by OMB. The AFFCR is working on establishing a generalized framework for how the assessments of climate-related financial risk can be conducted. This section is organized into the following sub-sections: (1) a description of current approaches used by Federal agencies to assess climate-related risk to assets and programs, (2) a description of currently available climate data and information products necessary to conduct climate-related financial risk assessments, (3) a proposed common framework for use across the Federal Government to assess climate-related financial risk and necessary technical inputs, (4) a description of next steps the AFFCR is taking to further develop the common framework and technical capabilities necessary for future annual assessments of climate-related financial risk for the Federal Budget.

Current Approaches for Assessing Climate-Related Risks

Here we present two ongoing activities across the Federal Government to assess climate risk to assets, programs, or other activities within the government. While these approaches do not necessarily seek to quantify financial risks, the methodological approaches inform and can be incorporated into the proposed common framework for climate-related financial risks.

Assessments Required for Agency Climate Adaptation Plans: Many agencies within the Federal Government have developed quantitative measures to assess climate vulnerabilities; however, agencies have not developed monetized estimates of climate-related financial risks (Gade et. al, 2020).[24] In response to EO 14030, agencies created Climate Adaptation Plans (CAP) "to evaluate the most significant climate-related risks and vulnerabilities for agency operations and missions, and identify action to manage those risks and vulnerabilities" (Council on Environmental Quality, n.d.). In many cases, financial impacts are only implicitly or tangentially mentioned, and given that there has not been previous Federal guidance quantifying climate-related financial risks, most agencies have not made an explicit connection between physical risks and financial risks. Both

[24] This statement also draws on personal communication with Department of Homeland Security (November 9, 2022), Department of Transportation (November 17, 2022), and Department of Commerce – National Oceanic Atmospheric Administration (November 7, 2022).

within and outside of the Federal government, the quantification of climate-related financial risk is a burgeoning area of research. For example, the U.S. Department of Agriculture (USDA) and the U.S. Department of Health and Human Services (HHS) outline the vulnerabilities and climate adaptation planning for their programs, such as decreased agricultural productivity driven by climate change impacting the demand for USDA programs and expanding "existing climate change-related public health and biomedical research activities" overseen by HHS (U.S. Department of Agriculture, 2021; U.S. Department of Health and Human Services, 2022). As part of the CAPs, agencies also assessed the climate vulnerabilities to real property and the development of quantitative metrics of climate vulnerabilities is part of their climate adaptation and resilience planning. The General Services Administration (GSA) is currently integrating environmental and climate justice factors to inform decisions related to real property (General Services Administration, 2022a). As part of GSA's climate adaptation planning, the agency also intends to quantitatively assess climate-related financial risk, and projects completion of this action by the end of FY2026 (General Services Administration, 2022b). At many agencies, the offices responsible for developing the CAP are not necessarily connected to the offices responsible for long-term budget planning (e.g., the Office of the Chief Financial Officer (OCFO)), although some agencies—including the General Services Administration— have assigned climate risk disclosure responsibilities to the OCFO explicitly built into their CAP (General Services Administration, 2022a).

Agency-Specific Qualitative Assessment Tools and Methods
In response to E.O. 14008, "Tackling the Climate Crisis at Home and Abroad" and E.O. 14057, "Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability", agencies have developed qualitative tools and assessments that assist the agencies in determining their climate vulnerabilities. These tools and assessments typically either provide highly detailed analyses for individual projects or are broad screening tools. The scope of most assessments undertaken to-date have included physical risk to assets (e.g., buildings and infrastructure).

Two examples of these tools include the Department of Defense (DoD) and Department of Homeland Security's (DHS) screening tools to assess exposure to climate-related risks for their assets and facilities. The DoD Climate Assessment Tool (DCAT) allows DoD personnel to identify the combined exposure if installations, related sites, their facilities, and infrastructure. The tool makes use of both historical extreme events and climate change projections to determine the climate exposure of an asset to help determine whether additional, more detailed information is needed to understand sensitivity and adaptive capacity. (Department of Defense, n.d.). Similarly, DHS developed a qualitative questionnaire-based vulnerability assessment tool to assign vulnerability scores to agency assets (Department of Homeland Security, 2022).

While these tools are essential for climate adaptation and resilience planning, the tools are not designed to demonstrate the Federal Budget's exposure to climate change. In other words, while the tools assess climate risks to assets (e.g., whether a mission-critical asset is vulnerable to sea level rise), the tools do not monetize the climate risk of the agency. Further work is needed to develop this analytical capability.

Available Federal Data and Modeling – Climate Data

Federal agencies maintain a range of scientific data products that provide climate change projections for various analytical purposes and agency- or program-specific management decisions[25]. For non-Sea Level Rise projections, a starting point is downscaled projections of Coupled-Model Intercomparison Project Phase 5 (CMIP5) climate model simulations (Taylor et al., 2012). Downscaling is a method that translates large-scale Global Climate Models (GCMs) data into a finer spatial resolution that can be used for specific decision or management contexts (Climate Adaptation Science Centers-U.S. Geological Survey, 2021). The NCA4 provided a series of statistically downscaled scenario products covering the period through 2100 for the purpose of developing NCA4, and have been since used in Federal climate projection data products (Avery et al., 2018).

Developing tools that support agencies' efforts to identify appropriate climate projections and the selection of climate scenarios relevant to an agency's or program's specific vulnerabilities, risk profile, or planning timescale of interest remains an ongoing effort. The 2022 Consolidated Appropriations Act directs the Office of Science and Technology Policy (OSTP) to develop a guide on the use of climate information and scenarios in Federal agency climate adaptation planning. This direction is repeated in the 2023 Consolidated Appropriations Act. The guidance will facilitate future updates to Federal Climate Adaptation Plans. Agencies may also use these tools in identifying appropriate climate projections and resources for assessing climate-related financial risk to the Federal Budget. One recent tool is the Climate Mapping for Resilience and Adaptation (CMRA) Assessment Tool (U.S. Global Change Research Program, 2022). CMRA was released in September 2022, as a joint effort among the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA), the Department of the Interior (DOI), and the White House. In addition to showing past and current climate risk exposure, the tool presents statistically downscaled projections of climate variables from NCA4 (National Oceanic and Atmospheric Administration, 2022). The scenarios are based on the Representative Concentration Pathway (RCP) scenarios 4.5 and 8.5. The projections are provided for three epochs: Early Century (2015-2044), Mid Century (2035-2064), and Late Century (2070-2099) (Avery et. al, 2018). Projections of climate variables in CMRA include:

- Temperature projections, such as annual days above 95 degrees, average minimum temperature, and average maximum temperature.
- Precipitation projections, such as average annual precipitation and annual number of days with measurable precipitation.
- Coastal inundation projections based on the results of the NOAA 2022 *Technical Report of Sea Level Rise* (Sweet et. al, 2022)

Other currently available downscaled climate resources and tools from Federal agencies and partner organizations include, but are not limited to, the following examples:

[25] Examples include NASA Earth Exchange Downscaled Climate Projections (NEX-DCP30), DOI USBR Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections (Maurer, E. P., L. Brekke, T. Pruitt, and P. B. Duffy (2007), 'Fine-resolution climate projections enhance regional climate change impact studies', Eos Trans. AGU, 88(47), 504.), US Forest Service National Forest Climate Change Maps, USACE's Climate Hydrology Assessment Tool, DOT FWHA's Climate Data Processing Tool (based on DOI USBR downscaled CMIP5 projections).

- U.S. Climate Resilience Toolkit (United States Global Change Research Program, n.d.a) and Climate Explorer (United States Global Change Research Program, n.d.b)
- NOAA's Sea Level Rise Viewer (National Oceanic and Atmospheric Administration, n.d.)
- 2022 Sea Level Rise Technical Report (Sweet et. al, 2022)
- Climate Risk and Resilience Portal (ClimRR) (Argonne National Laboratory, n.d.)
- Climate and Hazard Mitigation Planning (CHaMP) Tool (Urban Sustainability Directors Network and the Carolina, Great Lakes and Mid-Atlantic Regional Integrated Sciences and Assessments (CISA, GLISA, and MARISA) Programs, n.d.))
- NASA's Sea Level Change Tool (National Aeronautics and Space Administration, n.d.)
- NASA's NEX-GDDP-CMIP6 (Center for Climate Simulation, National Aeronautics and Space Administration, 2023)

Other natural hazard exposure resources are provided below, although the projected hazard exposure may not be based on downscaled global climate models:

- Drought.gov (National Integrated Drought Information System, National Oceanic and Atmospheric Administration, n.d.)
- Heat.gov (National Integrated Heat Health Information System, National Oceanic and Atmospheric Administration, n.d.)
- FEMA's National Risk Index (Federal Emergency Management Agency—Department of Homeland Security, n.d.)

In the fall of 2023, the Fifth National Climate Assessment (NCA5) will be released and projections used in the assembly of NCA5 can be used to update federal climate data and decision-making tools. NCA5 will use downscaled datasets for the continental U.S. that are based on CMIP6. These updated tools should be used in future climate-related financial risk assessments, including for the 2025 President's Budget.

Available Federal Data and Modeling – Facility & Program Data

Agency data on assets and outlays are essential to conducting these analyses. While the preliminary assessment on the flood risks to Federal facilities in this white paper utilizes the Federal Real Property (FRPP) Public Dataset, future assessments on Federal real property will need to evaluate alternatives to the FRPP dataset, given the FRPP dataset was not intended to evaluate site-specific physical risks. For example, to understand the flood risk exposure of a Federal facility, the analysts would need to know the location, elevation, and footprint of the building, rather than a single pair of coordinates for the address of the building. With respect to Federal programs, agencies maintain records of the outlays spent on individual programs, generally by fiscal year. Historical outlay data may or may not be required for projecting outlays under various climate scenarios. For example, the 2022 analysis on wildland fire suppression outlays did require historical outlays for the modeling, while the modeling for crop insurance premiums did not (Office of Management and Budget, 2022). However, regardless of whether the historical outlays are used within the modeling directly, these data provide important context for whether or not the projected outlays are in an explicable range. In addition to the data outlined above, agency data other than expenditures and revenue may be used when conducting the analysis, such as acres burned by wildland fire published by the National Interagency Fire Center (National Interagency Fire Center, n.d.).

In addition to the analysis presented earlier in this paper, there are a few sources of information on modeling the Federal Budget's exposure to climate risk. The 2022 white paper produced by OMB outlines how assessments were conducted for six programmatic areas: premium subsidies for the Federal Crop Insurance Program, Federal emergency relief for coastal disasters, Federal healthcare spending, Federal wildland fire suppression, Federal facilities' exposure to flood risk, and the National Flood Insurance Program (Office of Management and Budget, 2022). Additionally, the Department of Defense (DoD) produced updated policy to guide flood hazard assessments of DoD installations, which will be included in an update to DoDI 4165.70 Real Property Management (Department of Defense, 2022). While not specific to net outlays of the Federal Government, the Environmental Protection Agency's Framework for Evaluating Damages and Impacts (FrEDI) was released in 2021 and synthesizes the research of dozens of climate change studies conducted under the Climate Change Impacts and Risk Analysis (CIRA) project, which quantifies the economic damages in the U.S. by sector (Environmental Protection Agency, 2021). Economic damages by sector will not necessarily align with outlays or revenue losses of the Federal Government; however, FrEDI could be used for topics where there is compelling evidence that sectoral damages are correlated with Federal Government spending or revenues.

Proposed Common Framework to Assess Climate-related Financial Risk for the Federal Budget

The assessment of the Federal Budget's exposure to climate change is comprised of analyses on federally-owned assets and specific Federal programs. In future years, the cost of changes induced by climate change in mission and operations may be explored. These components will be assessed using a common structure and set of assumptions. The assessment will examine the impact of the physical risks of climate change. The physical risks are the direct result of the changes in climate on the current environment, such as increased frequency and intensity of natural disasters on infrastructure. The other form of risk from climate change is transition risks, which are not examined in this assessment, although this is a potential area for further research. Transition risks are the consequences of taking policy actions to shift the economy away from fossil fuels.

Generally, the Federal Budget's exposure to climate risk is measured as the projected change in real dollars of net outlays of the Federal Budget caused by climate change. By focusing on net outlays, this narrows the scope of what is examined relative to other economic analyses on the physical impacts of climate change. The literature on the Federal Budget's exposure to climate change is limited, while there is a rich literature on the impacts of climate change on a wide variety of economic sectors. Unfortunately, there are only a select number of cases where assuming the outlays of the Federal Government will be proportional to economic losses of a particular sector is appropriate.

The Assessments of Federal Financial Climate Risks (AFFRC) Interagency Working Group is developing an overarching framework for assessing the climate-related financial risks to physical assets, programs, agency missions, and operations of the Federal Government. A common set of technical assumptions, climate data resources, and climate scenarios will underpin these assessments. These common assumptions for future assessments could include:

- Common climate scenario options: For example, if following the science of the Fourth National Climate Assessment, a "low warming scenario" would use Representative Concentration Pathway (RCP 4.5), and a "high warming scenario" would use RCP 8.5 (Avery et. al, 2018).
- For the time periods evaluated, the assessment could project net outlays for the mid-21st century and late 21st century.
- Establishing a common baseline for assessment interpretation: If in alignment with analysis conducted under Section 6(a) of E.O. 14030, which this year examined three climate change scenarios in the Long-term Budget Outlook, projected loss or expenditures can be compared to an optimal policy scenario such as the U.S. Long-Term Strategy that is consistent with a 1.5° C pathway through 2050 (U.S. Department of State and the U.S. Executive Office of the President, 2021). Alternatively, a historical baseline could be used that would show the possible bias introduced by using historical data and not accounting for future climate change.

Modeling Physical Asset Risk

The projected losses to physical assets will aim to use an expected value approach—like the method used in this year's assessment of flood risk to Federal facilities—although refining this method will take further development. The expected value approach considers the value exposed and the likelihood of an event causing loss, as expressed in equation (1):

$$Expected\ Annual\ Loss = Exposure \times Annualized\ Frequency\ of\ Loss \times Loss\ Ratio \quad (1)$$

Exposure is the total value of the asset at risk in a loss event. Annualized frequency is the projected reoccurrence of the event and the loss ratio is the percent of the replacement value estimated to be damaged by the loss event. This is the same general approach used by the Federal Emergency Management Agency (FEMA) for their Expected Annual Loss methodology of the National Risk Index, which estimates regional damages to agriculture, population, and buildings (Federal Emergency Management Administration, 2022). As with any projected losses, there is uncertainty that must be accounted for in the analysis, which at a minimum should be described qualitatively. Additionally, efforts would need to be taken across agencies to standardize the methodologies used to estimate values of exposure and loss, in order to ensure estimates are comparable between one agency and another.

Modeling & Data Needs in Connecting Physical Asset Risks to Financial Risks

Climate change presents a significant risk to the Federal portfolio of physical assets (buildings, infrastructure, and other fixed capital), given the Federal Government is financially responsible for any damages from natural disasters that occur to its own assets. This also includes assets that are climate-sensitive, such as dams, irrigation infrastructure, and flood levees, which also present risks where they may under-perform (i.e., service reduction) due to a changing climate. Related to the discussion earlier on using an expected value approach to developing projections of annual losses to the Federal portfolio of physical assets, this method requires three key pieces of information to formulate a dollar value of losses:

- Exposure: Improving the estimates of Federal assets' exposure requires accurate, consistent, and transparent accounting of Federal real property.

- Frequency of climate-related events: The availability of widely accessible models for the frequency of climate-related events varies by the type of event and geography. For example, while the projected annual frequency of days over 100 degrees Fahrenheit under different climate scenarios are accessible from the downscaled data of NCA4, there are not easily available projections for the frequency of hurricanes under different climate scenarios.

- Factor of Loss: In many cases exposure to a climate stressor will not result in a complete loss of the physical asset. Therefore, a "factor of loss" aids in creating a projection of the value loss. Incorporating the intensity and duration of the event aids in developing a more accurate factor, in addition to accounting for the sensitivity of the asset. Options are currently limited in developing a factor of loss that could easily be applied and is an area in significant need of further research.

A caveat to the above approach is that this method is being proposed specifically for Federal facilities. Methods suitable for climate-sensitive assets, such as flood control structures, will require the AFFCR to explore currently available research to determine a method for assessing the climate-related financial risks to these assets.

Modeling Changes in Expenditures of Federal Programs

The physical impacts of climate change on Federal programs can vary depending on the structure of the program. Certain programs could experience greater outlays as a result of climate change. This includes programs that respond to the physical risks of climate change, such as wildland fire suppression, Stafford Act Programs, and other Federal programs pertaining to emergency management. There are also programs that experience increased outlays, but the mission of the program is broader than responding to climate-related events. This includes Federal health care programs, which were discussed in last year's assessment. NCA4 discusses the broad range of health impacts that are associated with climate change (Ebi et. al, 2018). Given that in 2021, Medicare spending composed 21 percent ($900.8 billion) of total National Healthcare Expenditures and Medicaid composed $734.0 billion (17 percent), there is sufficient evidence to assume that a significant portion of the increase in national health expenditures as a result of climate change would be absorbed by Federal healthcare spending (Environmental Protection Agency, 2017; Carleton et. al, 2022)). For credit programs, climate change may increase default risk of direct loans from the Federal Government and loans guaranteed by the Federal Government. Borrowers who are unable to sufficiently recover financially from climate-related events could experience higher rates of delinquency and default. Such loan programs presently underestimate systemic portfolio-wide risk and costs to the Federal Government, because disaster loss mitigation programs, private and Federal insurances, and Federal assistance dollars are protective against default and effectively shift portfolio hazard risk onto state and federal entities.

Some Federal programs may experience decreased revenue caused by climate change, particularly given that climate change can cause disruptions to trade and may cause economic losses to a wide range of industrial sectors (Smith et al., 2018). Ongoing work responding to Section 6(a) in the

Executive Order 14030, "Climate-related Financial Risks" will quantify the macro-economic costs of climate change and could be used in concert with other tools to inform revenue projections. Lastly, some programs may have their efficacy impacted by climate change, but not experience higher outlays or decreased revenues; instead, the program may experience a fall in performance metrics, such as members of the public served.

Given the wide diversity of Federal programs, there is no "one size fits all" approach when developing projections of expenditure changes for individual programs. For each program, the appropriate climate variables need to be chosen to best model how expenditures are projected to change under different climate change scenarios. Below we describe three general approaches for modeling the impact of climate risk on expenditures for Federal programs, which aim to contribute to a dialogue for future agency modeling while allowing flexibility to account for differences among Federal programs.

<u>Modeling Approach #1:</u> Comprehensive Modeling of Physical Damages and Expenditures: For certain programs, a comprehensive modeling structure may be considered. This would not only provide the Federal Budget's exposure, but non-monetary outcomes of climate change as well. For example, the analysis on wildland fire suppression in the 2022 white paper provided projections of acres burned by wildland fire, in addition to the projections of outlays for wildland fire suppression from the U.S. Forest Service and the Department of the Interior (Office of Management and Budget, 2022). Developing comprehensive modeling requires substantial investment by the Federal Government for an individual program, since the modeling of a specific program's mechanics is unlikely to translate to other Federal programs. For these models, the modeling will generally have three stages.

1. Climate projections: Agencies will utilize guidance provided by the AFFCR on the selection and use of appropriate climate projections, including sea-level rise, and associated variables to ensure consistency throughout the assessment.

2. Physical damages of climate change: Agencies develop a model, if needed, that translates the climate projections into the physical impact of interest (e.g., acres burned by wildland fire, health impacts from poorer air quality, damage to infrastructure, buildings loss).

3. Federal financial damage of climate change: Agencies develop a model that estimates the cost to the Federal Government based on the physical damages projected in the previous stage.

<u>Modeling Approach #2:</u> Modeling Expenditures Directly from Climate Variables: Given the resource intensity of developing comprehensive modeling for individual Federal programs, a more streamlined framework would involve establishing a relationship between historical climate variables[26] and outlays, then utilizing the relationship to develop projections of outlays under different climate change scenarios. Additionally, where there is a demonstrated relationship between program expenditures and climate variables, agencies could explore the possibility of using the correlation among Federal outlays of different programs to investigate whether the

[26] In addition to historical climate variables, the attribution and detection of extreme weather on the impact of Federal programs could be considered.

relationship between climate variables and the outlays of one Federal program can also be used to explain other programs' responses to climate change. Method development would need to address suitable approaches for characterizing non-linear relationships between changes in climate variables and program expenditures.

<u>Modeling Approach #3:</u> Modeling Expenditures as a Proportion of Economic Damages: The outlays of the Federal Program could be assumed to be proportional to the sectoral damages projected in FrEDI (Environmental Protection Agency, 2021). While this method would require the least amount of additional modeling, further research would need to be conducted to ensure that assuming outlays increase proportionally with economic damages to a particular sector included within FrEDI is reasonable.

Modeling & Data Needs for Expenditures of Federal Programs
Given the wide range of Federal programs, subject matter expertise in the individual programs is essential for developing modeling to project expenditures under different climate scenarios. These subject matter experts (SMEs) will need to assess which of the three approaches above are best suited for the program of interest. Under all three approaches, the analysts should obtain a historical record of program outlays or losses to ensure that any projections follow logically from past events. For example, given that drought intensity and frequency are projected to increase, one would expect a Federal program mitigating drought impacts to likely have increasing expenditures in the projections.

Comprehensively modeling the physical impacts and change in expenditures from climate change is a multi-disciplinary effort. The SMEs will first need to identify the physical impacts of climate change that are believed to affect the program expenditures. Once the physical impacts are identified, creating the model connecting the climate variables to the physical impacts will require coordination with experts in the physical sciences, within or outside of the agency. Furthermore, establishing relationships between the physical impacts and the program expenditures requires economic modeling. Therefore, this modeling approach requires a team of individuals that have a deep understanding of how the program is implemented, are able to model the physical impacts of climate change that affect the program, and have an understanding of the appropriate economic modeling for developing the relationship between physical impacts and program expenditures, along with projecting the expenditures under different climate change scenarios.

Under the second approach—modeling expenditures directly from climate variables— where there is a demonstrated relationship between program expenditures and climate variables, the analysts would develop a regression model with a measure of the expenditures as the response variable and the historical climate variables as the explanatory variables. After the analyst has created the regression model, the projected climate variables can be inserted into the regression formula to output the projections of expenditures. The projected output of the high (low) warming scenario would then be subtracted from the output of the baseline scenario. This result allows the analysts to identify the impact of the high (low) warming scenario relative to the baseline.

For the third approach—modeling expenditures as a proportion of economic damages, SMEs would need to examine how the program functions relative to economic sectors (e.g., whether the program is designed to run cyclical or counter-cyclical would a particular economic indicator).

Then the analyst can use the average historical proportion of program outlays to the economic indicator as the multiplier to economic damages from FrEDI.

Modeling Mission and Operational Risks

Mission and operational risk in many cases will not explicitly impact the outlays of the agency, but rather cause the performance of the agency to decline given funding constraints. The risk to operations brought on by climate change is diverse. Impacts to mission and operations may include:

- Disruptions in continuity of operation, including disruptions caused within supply chains of federally procured goods and services.
- Loss of assets not owned by the Federal Government but in which the Federal Government has a vested interest in maintenance.
- Reduced ability to meet mission and functional performance. For example, climate-related risks to NASA's critical launch facilities (National Aeronautics and Space Administration, 2021) or current technologies to assist in agricultural conservation decreasing in effectiveness due to climate change (U.S. Department of Agriculture, 2021).

At this time the AFFCR is not actively establishing a framework for quantifying mission and operations risks; however, as data collection continues and research in this area may grow, the AFFCR will explore the feasibility of creating a framework for quantifying the impacts on operations and mission risk in the future.

Continued Work to Develop the Common Framework and Methodology for Future Assessments

The assessment included in this year's paper presents advances in incorporating forward-looking projections of climate change and multiple approaches to estimate how changes in climate variables and natural hazards (e.g., flooding) relate to potential future risk to Federal assets and programs. This work has built on the continued growth of accessible climate information (e.g., NCA4 downscaled projections, CMRA, flooding projections from Federal and external providers), and further work remains to link projections in changes to physical variables to Federal Budget decision contexts. To support future assessments, the AFFCR is working in several areas: (1) continuing to develop the common framework, provide technical guidance, and examples of implementation across a range of Federal assets and programs, (2) identifying necessary and emerging climate data and information resources, including projections of extreme weather events where information is currently unavailable (e.g., projecting physical impacts of tropical cyclones), and (3) increasing capacity and training of Federal agencies to conduct climate-related financial risk assessments.

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Appendix: Flood Risk to Federal Civilian Facilities

Table A.1 Count of Owned Real Property Types and Use from the Federal Real Property Public Data Set for FY2020.

Real Property Types and Uses	Count of Owned Real Property
Building	**100,541**
All Other	17,688
Aviation Security Related	31
Border/Inspection Station	309
Child Care Center	30
Comfort Station/Restrooms	5,475
Communications Systems	1,368
Data Centers	75
Dormitories/Barracks	2,636
Facility Security	130
Family Housing	15,091
Hospital	707
Industrial	5,491
Laboratories	3,104
Land Port of Entry	404
Museum	41
Navigation and Traffic Aids	269
Office	8,515
Other Institutional Uses	7,065
Outpatient Healthcare Facility	682
Post Office	18
Prisons and Detention Centers	1,510
Public Facing Facility	132
School	2,273
Service	11,830
Warehouses	15,667
Land	**30,340**
Agriculture	39
Airfields	4
All Other	1,118
Communications Systems	132
Flood Control and Navigation	377
Forest and Wildlife	311
Grazing	9
Harbor and Port	9
Housing	98

Industrial	15
Institutional	647
Miscellaneous Military Land	3
Navigation and Traffic Aids	928
Office Building Locations	180
Outpatient Healthcare	9
Parks and Historic Sites	418
Post Office	1
Power Development and Distribution	3,644
Reclamation and Irrigation	21,982
Research and Development	365
Storage	32
Training Land	7
Vacant	12
Structure	**155,821**
Airfield Pavements	228
All Other	19,689
Communications Systems	4,025
Flood Control and Navigation	1,168
Harbors and Ports	1,781
Industrial (other than buildings)	1,766
Miscellaneous Military Facilities	11
Monuments and Memorials	1,474
Navigation and Traffic Aids (other than buildings)	20,466
Parking Structures	16,668
Power Development and Distribution	750
Railroads	268
Reclamation and Irrigation	11,287
Recreational (other than buildings)	25,178
Renewable Energy System	60
Research and Development (other than Laboratories)	362
Roads and Bridges	29,725
Service (other than buildings)	1,451
Space Exploration Structures	80
Storage (other than buildings)	6,332
Utility Systems	12,941
Weapons Ranges	111
Grand Total	**286,702**

Table A.2: Classification of Building Archetypes for Nofal and van de Lindt (2020)

Building Archetype	Building Description
F1	One-story single-family residential building on a crawlspace foundation
F2	One-story multi-family residential building on a slab-on-grade foundation
F3	Two-story single-family residential building on a crawlspace foundation
F4	Two-story multi-family residential building on a slab-on-grade foundation
F5	Small grocery store/Gas station with a convenience store
F6	Multi-unit retail building (strip mall)
F7	Small multi-unit commercial building
F8	Super retail center
F9	Industrial building
F10	One-story school
F11	Two-story school
F12	Hospital/Clinic
F13	Community center (place of worship)
F14	Office building
F15	Warehouse (small/large box)

Table A.3: Classification of Federal Real Property Profile (FRPP) cross walked to Nofal et. al (2020) archetypes

FRPP Real Property Type	FRPP Real Property Use	Nofal Archetype Allocation
Building	Service	Warehouse (small/large box)
Building	Prisons and Detention Centers	Hospital/Clinic
Building	Industrial	Industrial building
Building	Warehouses	Warehouse (small/large box)
Building	School	One-story school
Building	Laboratories	Industrial building
Building	Family Housing	Two-story multi-family residential building on a slab-on-grade foundation
Building	Office	Small multi-unit commercial building
Building	Dormitories/Barracks	Two-story multi-family residential building on a slab-on-grade foundation
Building	Other Institutional Uses	Multi-unit retail building (strip mall)
Building	Outpatient Healthcare Facility	Hospital/Clinic
Building	Hospital	Hospital/Clinic
Building	Facility Security	Office building
Building	Child Care Center	One-story school
Building	Comfort Station/Restrooms	Multi-unit retail building (strip mall)
Building	Museum	Office building
Building	Border/Inspection Station	Warehouse (small/large box)
Building	Post Office	Office building
Building	Data Centers	Industrial building
Building	Land Port of Entry	Warehouse (small/large box)
Building	Public Facing Facility	Office building
Building	Aviation Security Related	Office building