The Cost of Climate Change to a Person Born in 2024
Appendix: Details on Methodology

Contents

Introduction

This Appendix describes the methodology used to generate the estimates provided in the "Cost of Climate Change to a Person Born in 2024" report.

This analysis draws from a growing body of literature on the impacts of climate change in the United States (e.g., the U.S. National Climate Assessment). Available literature tends to focus on sectors and organizations (e.g., governments, communities) rather than impacts to individual citizens. Where literature does address impacts to individuals, it tends to be narrowly focused on specific issues (e.g., health impacts). The literature that monetizes climate change impacts at the consumer level is relatively new. This analysis draws on that nascent field of research to explore how climate change is projected to impact individual consumers over their lifetime.

A relatively novel aspect of this study is that it brings together existing issue-specific research to begin to provide a more comprehensive picture of what climate means for household finances, including impacts to consumers' expenditures and net income. As noted in the main report, there are several factors that were not incorporated into our quantitative estimates, thereby leading to an underestimate of how climate change impacts consumer expenses and net income. As the research grows, subsequent analyses could attempt to more comprehensively include these factors.

As noted in the report, the analysis is subject to considerable uncertainty. The sources of uncertainty arise from multiple factors[1], including:

- Future greenhouse gas (GHG) emissions, which depend on choices made by society, the evolution of technology, and other factors. We have encapsulated some of this uncertainty by analyzing two different emissions scenarios.
- Estimation of atmospheric GHG concentrations from GHG emissions. GHGs are cycled into and out of the atmosphere by a wide array of biogeochemical processes, not all of which are completely understood or well-represented in the biogeochemical models needed to translate emissions into atmospheric concentrations. This uncertainty is reflected in part by the two scenarios of radiative forcing (RCP 2.6 and 7.0) used in this study.
- Climate modeling, which uses atmospheric GHG concentrations as an input. While climate models have improved greatly over the past four decades and provide useful insight into how climate change will be manifested as atmospheric GHG concentrations change, they are subject to uncertainty, including concerning the magnitude of global warming that will occur at a

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[1] See, e.g.: Smith, K.A., Wilby, R.L., Broderick, C., Prudhomee, C., Matthews, T., Harrigan, S., and Murphy, C., 2018. Navigating cascades of uncertainty – As easy as ABC? Not quite… *J. Extreme Events*, 5(1), 1850007. DOI: 10.1142/S2345737618500070

specified GHG concentration[2] and the representation of extreme events.[3] This uncertainty is addressed in some of the climate impact studies that underlie our analysis. However, we did not explicitly represent that uncertainty in our results.

- Impact estimation. There is uncertainty concerning the impact that a unit of climate change will have. In some cases, this requires estimating the impact to a system (e.g., an electrical grid, an agricultural system) or an organization (e.g., a government or community) and then translating those impacts to the individual level. It can also require considering the interactions between systems (e.g., the effects of changes in electrical grid reliability on manufacturing). In addition, it also requires accounting for adaptation, since there are often measures that can be taken to reduce the effect of an unmitigated impact. Finally, there is uncertainty associated with translating damage or impairment (or opportunities) into monetary terms. In this study, we have attempted to use some of the most advanced, relevant research, which typically accounts for some of these factors, but, generally, not all of them. As with the uncertainty associated with climate modeling, we did not attempt to approximate the extent of the uncertainty associated with the impact estimation.

Nonetheless, as the first analysis of its type, we believe that it constitutes a useful, order-of-magnitude representation of the potential impacts of climate change on the household finances of a person born in 2024. Our bottom-line conclusion is that the cost of climate change to a baby born in 2024 in America will be close to $1 million is based on our estimate of a loss of net income of $630,000, increased expenses of $260,000, and the unquantified factors that we cite throughout the report and in this Appendix. Although the actual impact could be higher or lower than $1 million, we are confident that the impact will be substantial.

The reader may ask whether factors that were not explicitly included in the analysis could significantly drive down the net monetary impact. Examples of this include expansion of warm-weather-dependent income in cold climates (e.g., outdoor construction in Maine; agriculture in North Dakota), reduction in heating costs, reduction in snow-related traffic accidents, etc. In most cases, the deleterious effects of a particular type of climate change outweigh the positives, when considering the nation as a whole. An example is the effect of warmer temperatures on electricity demand. Numerous studies indicate that the increase in air conditioning demand associated with higher temperatures will be significantly greater

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[2] The latest assessment from the Intergovernmental Panel on Climate Change indicates that the global average, long-term warming that would be associated with a doubling of the atmospheric concentration of carbon dioxide above its pre-industrial value is between 2 and 5 ^{o}C. Forster, P., T. Storelvmo, K. Armour, et al., 2021. The Earth's Energy Budget, Climate Feedbacks, and Climate Sensitivity. In *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, et al., (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 923–1054, doi:10.1017/9781009157896.009.

[3] Seneviratne, S.I., X. Zhang, M. Adnan, et al., 2021. Weather and Climate Extreme Events in a Changing Climate. In *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, et al. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1513–1766, doi: 10.1017/9781009157896.013.

than the heating demand decrease.[4] Overall, the scientific literature consistently indicates that the net economic effect of climate change on the United States is negative.[5]

There is the potential to significantly refine the estimates provided in this study by:

- Drawing on a broader range of underlying studies and using that to paint a clearer picture of the scale of the uncertainty.
- Encompassing more spatial, sectoral, and socioeconomic detail and realism associated with each specific impact.
- Including several elements that were not included such as supply chain impacts, a broader range of employment impacts, a more comprehensive set of health impacts, and others – most of which will tend to increase the cost estimates.
- Encapsulating cost estimates within a modeling framework that explicitly accounts for interdependencies between sectors.
- Explicitly accounting for adaptation.

Inputs to the Analysis

Scenarios

This section outlines the two climate change scenarios used in the study to depict a range of conditions for the world that a baby born in 2024 may experience throughout their lifetime.

In consultation with Consumer Reports (CR), ICF decided to utilize Shared Socioeconomic Pathways (SSPs) as future scenarios. The SSPs form the cornerstone of recent projections in climate change research, developed collaboratively by a global team of scientists, economists, and modelers. The SSPs offer a range of future scenarios, encompassing changes in population, economic growth, education, urbanization, energy use, and technological advancement. To quantify these socioeconomic scenarios, researchers utilized integrated assessment models (IAMs), which translated the SSPs' socioeconomic conditions into projections of future energy use and greenhouse gas (GHG) emissions. The SSPs are interconnected with the Representative Concentration Pathways (RCPs), an earlier set of climate scenarios. SSPs describe the socioeconomic paths and decisions leading to various climate futures, whereas RCPs are primarily focused on the change in the atmospheric energy balance that leads to climate change. Together the SSPs-RCPs form a framework that offer a unified approach for describing climate change scenarios, which depict diverse outlooks on societal factors, including demographics, development, governance, and technological advancements.[6]

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[4] See, e.g., the following study and references therein: McFarland, J., Zhou, Y., Clarke, L., et al., 2015. Impacts of rising air temperatures and emissions mitigation on electricity demand and supply in the United States: a multi-model comparison. *Climatic Change*, volume 131, 111–125. https://link.springer.com/article/10.1007/s10584-015-1380-8

[5] Hsiang, S., Greenhill, S., Martinich, J., et al., 2023. Ch. 19. Economics. In: *Fifth National Climate Assessment*. Crimmins, A.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, B.C. Stewart, and T.K. Maycock, Eds. U.S. Global Change Research Program, Washington, DC, USA. https://doi.org/10.7930/NCA5.2023.CH19

[6] Gurney, K.R., Kılkış, S., Seto, K.C., et al., 2022. Greenhouse gas emissions from global cities under SSP/RCP scenarios, 1990 to 2100, *Global Environmental Change*, p3, retrieved from: Greenhouse gas emissions from global cities under SSP/RCP scenarios, 1990 to 2100 - ScienceDirect.

In consultation with CR, the ICF team selected SSP1-2.6 and SSP3-7.0. SSP1-2.6 represents a low GHG emissions scenario, characterized by an increasing shift toward sustainable practices. Under this scenario, CO_2 concentrations are projected to decline to net zero around 2070, followed by net negative CO_2 emissions[7]. Temperatures are expected to peak in the United States in the 2070s before declining over the last two decades of the century.

SSP3-7.0 depicts a high GHG emissions scenario with little investment in education or health in poorer countries coupled with a fast-growing population and increasing inequalities. GHG emissions roughly double from current levels by 2100.

Temperature and Precipitation Data

ICF calculated relevant climate conditions from the NEX-GDDP (NASA Earth Exchange Global Daily Downscaled Projections) downscaled CMIP6 (Climate Model Intercomparison Project 6) daily temperature and precipitation datasets, which include output from state-of-the-art climate models. To determine nationwide and city-specific climate projections, ICF ran calculations on all grid cells falling within the continental United States for all years between 1975 and 2100. ICF calculated modeled change values from a 1995 baseline (1986-2005) for all years with calculated data and fit the annual projections to a curve to capture climate trends and to encompass natural interannual variability. ICF calculated nation-wide averages and city-specific projections for the following variables –

- Annual average temperatures
- Cooling and Heating Degree Days
- Hottest summer temperatures
- Coldest winter temperatures
- Days with maximum temperatures over 27°C, 32°C, 38°C
- Days with precipitation under 12.5 mm
- Days with precipitation over 12.5 mm, 25 mm, 50 mm
- Total annual precipitation

ICF used an in-house tool, ClimateSight, to calculate the above variables from the publicly available NEX-GDDP global gridded dataset, which is available in NetCDF format.

Baseline

ICF used a 20-year period from 1986 to 2005, with the central point of 1995, as the baseline for comparison to future climate conditions. This aligns with that of the Intergovernmental Panel on Climate Change (IPCC), which uses the same baseline period. The 20-year baseline was chosen to capture larger climate trends and account for interannual variability. The use of a two-decade span provides a reliable framework for identifying long-term climatic patterns. It is important to note that the value for 1995 is an5veragee, taken from the surrounding 20 years of data, meaning the actual annual value for 1995 may differ slightly from this average.

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[7] IPPC Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)] (2021). "Climate Change 2021: The Physical Basis", Cambridge University Press, p13, retrieved from: Climate Change 2021: The Physical Science Basis (ipcc.ch).

Polynomial Fitting & Extrapolation

ICF subsequently utilized polynomial fitting techniques to identify trends in the climate data. Recognizing the unique characteristics of different data sets, a tailored approach was employed, to avoid both underfitting (i.e., missing key temporal variations) and overfitting (i.e., using a higher order polynomial than necessary). For mean temperature data, a 5th degree polynomial fit was utilized. This decision was driven by the need to capture trends potentially influenced by fluctuations in greenhouse gas emissions. A 5th degree polynomial ensures these trends are distinctly visible in the temperature data analysis. For the other climate data types, we opted for a simpler 2nd degree polynomial, calculated using the LINEST function in Excel.

The calculations for the 5th degree polynomial fit for the mean temperature data was performed using a custom R function, *fit_and_predict.* This function employs direct polynomial fitting through the *poly* function (with *raw=TRUE*). An integral part of this process was the implementation of a weighting scheme, prioritizing earlier years in the dataset. This approach was taken to ensure a smooth fit at the beginning of the time series. The polynomial equations are shown below.

Mean Temperature

SSP1-2.6: $Y = 7.025812\times10^{-12}\cdot x^5 - 2.938897\times10^{-4}\cdot x^3 + 1.201586\cdot x^2 - 1.841687\times10^3\cdot x + 1.003323\times10^6$

SSP3-7.0: $Y = 3.269765\times10^{-12}\cdot x^5 - 1.360855\times10^{-4}\cdot x^3 + 0.5552431\cdot x^2 - 8.494891\times10^2\cdot x + 4.620573\times10^5$

Annual Days Over 27 Degrees Celsius

SSP1-2.6: $\mathrm{Y} = -0.00403\cdot x^2 + 0.824461\cdot x - 13.7249$

SSP3-7.0: $\mathrm{Y} = 0.000992\cdot x^2 + 0.473497\cdot x - 9.85263$

Annual Days Over 32 Degrees Celsius

SSP1-2.6: $\mathrm{Y} = -0.00349\cdot x^2 + 0.713667\cdot x - 11.7205$

SSP3-7.0: $\mathrm{Y} = 0.00242\cdot x^2 + 0.289714\cdot x - 6.97521$

Annual Days Over 38 Degrees Celsius

SSP1-2.6: $Y = 0.000138\cdot x^2 + 0.144622\cdot x - 3.04625$

SSP3-7.0: $Y = 0.002534\cdot x^2 - 0.05057\cdot x - 0.51602$

Annual Days with Precipitation Over 12.5 Millimeters

SSP1-2.6: $Y = -7.32492^{-5}\cdot x^2 + 0.021065\cdot x - 0.40993$

SSP3-7.0: $Y = 1.96759^{-5}\cdot x^2 + 0.012425\cdot x - 0.27301$

Annual Days with Precipitation Over 25 Millimeters

SSP1-2.6: $Y = -6.32760^{-5}\cdot x^2 + 0.01464\cdot x - 0.28663$

SSP3-7.0: $Y = 2.45432^{-5}\cdot x^2 + 0.007954\cdot x - 0.20447$

Annual Days with Precipitation Over 50 Millimeters

SSP1-2.6: $Y = -1.50624^{-5} \cdot x^2 + 0.003295 \cdot x - 0.05799$

SSP3-7.0: $Y = 6.42157^{-6} \cdot x^2 + 0.001642 \cdot x - 0.03825$

Annual Days with Precipitation Under 12.5 Millimeters

SSP1-2.6: $Y = 7.32492^{-5} \cdot x^2 - 0.02106 \cdot x + 0.409932$

SSP3-7.0: $Y = -1.96759^{-5} \cdot x^2 - 0.01243 \cdot x + 0.27301$

Annual Average Precipitation

SSP1-2.6: $Y = -0.00298 \cdot x^2 + 0.800415 \cdot x - 15.3241$

SSP3-7.0: $Y = 0.000318 \cdot x^2 + 0.451375 \cdot x - 9.69748$

Maximum Summer Temperature Above Baseline

SSP1-2.6: $Y = -0.00034 \cdot x^2 + 0.069245 \cdot x - 1.1631$

SSP3-7.0: $Y = 0.000136 \cdot x^2 + 0.36786 \cdot x - 0.80166$

Minimum Winter Temperature

SSP1-2.6: $Y = -0.000453 \cdot x^2 + 0.09540 - 1.426$

SSP3-7.0: $Y = 0.00028 \cdot x^2 + 0.04203 - 0.8497$

Annual Cooling Degree Days

SSP1-2.6: $Y = -0.06717 \cdot x^2 + 14.05178 \cdot x - 237.142$

SSP3-7.0: $Y = 0.057807 \cdot x^2 + 5.216656 \cdot x - 136.83$

Annual Heating Degree Days

SSP1-2.6: $Y = 0.12773 \cdot x^2 - 26.06544 + 434.31061$

SSP3-7.0: $Y = -0.02294 \cdot x^2 - 15.00673 + 309.93406$

Table 1 shows the results of the polynomial fitting for the indicated years.

Table 1. Smoothed Climate Variables[8]

Year	2034	2044	2064	2084	2104
Mean Temperature					
Low Scenario (SSP1-2.6)	1.64	1.91	2.12	2.03	2.03
High Scenario (SSP3-7.0)	1.66	2.13	3.07	4.11	5.46
Days over 27°C					
Low Scenario (SSP1-2.6)	21.25	24.26	27.86	28.25	25.41
High Scenario (SSP3-7.0)	22.13	28.15	40.80	54.24	68.47
Days over 32°C					

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[8] In the Appendix, numbers are presented with a variety of significant digits, corresponding to the native precision of the calculations. However, as indicated in the report, the confidence that should be ascribed to the numbers generally corresponds to two significant digits, or less.

Low Scenario (SSP1-2.6)	18.53	21.12	24.22	24.53	22.04
High Scenario (SSP3-7.0)	19.12	25.16	38.70	54.17	71.58
Days over 38°C					
Low Scenario (SSP1-2.6)	6.13	7.76	11.09	14.54	18.09
High Scenario (SSP3-7.0)	5.58	8.36	15.46	24.58	35.73
Summer Max Degrees Above Baseline					
Low Scenario (SSP1-2.6)	1.77	2.02	2.32	2.34	2.09
High Scenario (SSP3-7.0)	1.90	2.44	3.61	4.90	6.29
Winter Min Temperature					
Low Scenario (SSP1-2.6)	2.67	3.03	3.49	3.59	3.32
High Scenario (SSP3-7.0)	2.67	3.45	5.19	7.14	9.31
Total Annual Precipitation					
Low Scenario (SSP1-2.6)	21.97	22.41	26.11	36.67	38.38
High Scenario (SSP3-7.0)	18.53	19.02	23.46	43.81	54.36
Annual Precipitation <12.5mm					
Low Scenario (SSP1-2.6)	-0.59	-0.71	-0.89	-1.02	-1.09
High Scenario (SSP3-7.0)	-0.54	-0.69	-1.00	-1.33	-1.67
Annual Precipitation >12.5mm					
Low Scenario (SSP1-2.6)	0.59	0.71	0.89	1.02	1.09
High Scenario (SSP3-7.0)	0.54	0.69	1.00	1.33	1.67
Annual Precipitation >25mm					
Low Scenario (SSP1-2.6)	0.36	0.43	0.52	0.56	0.55
High Scenario (SSP3-7.0)	0.36	0.47	0.71	0.97	1.24
Annual Precipitation >50mm					
Low Scenario (SSP1-2.6)	0.09	0.10	0.12	0.12	0.12
High Scenario (SSP3-7.0)	0.08	0.11	0.16	0.22	0.28
Cooling Degree Days					
Low Scenario (SSP1-2.6)	364.15	417.35	483.44	495.79	454.41
High Scenario (SSP3-7.0)	384.28	511.59	800.91	1136.47	1518.28
Heating Degree Days					
Low Scenario (SSP1-2.6)	-669.79	-764.39	-876.97	-887.36	-795.56
High Scenario (SSP3-7.0)	-673.05	-852.94	-1226.47	-1618.36	-2028.60

Socioeconomic Data Inputs

GDP without climate impacts

ICF obtained data about the forecasted US Gross Domestic Product (GDP) from the OECD[9]. The dataset projects the US GDP up to 2060 in 2010 dollars. ICF performed a linear regression in Excel using the LINEST function to further project the US GDP out to 2104, using the following formula: Y = 396,893x + 20,296,980. Subsequently, ICF converted US 2010 dollars to 2024 dollars.

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[9] OECD (2024), "Real GDP long-term forecast (indicator)". Accessed January 30, 2024. GDP and spending - Real GDP long-term forecast - OECD Data

Gasoline and Electricity

To analyze gasoline prices, our team utilized data[10] from the 4th version of the Global Change Assessment Model (GCAM).[11] This version was chosen over more recent iterations because it differentiates between gasoline prices with and without carbon taxes. However, it's important to note that this data set did not include the SSP3-7.0 scenario. As a substitute, we used a similar scenario, SSP3-6.0.

Table 2. Gasoline Prices.

SSP1-2.6	Unit	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
GCAM4	US$2024/gallon	$2.14	$2.23	$2.35	$2.48	$2.56	$2.64	$2.70	$2.75	$2.77	$2.74
GCAM4	US$2024/t C02	$ -	$ -	$25.78	$42.00	$68.41	$111.43	$181.52	$295.67	$481.61	$784.50
GCAM4	US$2024/t CO2	$ -	$ -	$39.62	$64.53	$105.11	$171.22	$278.90	$454.30	$740.01	$1,205.40
GCAM4	US$2024/gallon	$ -	$ -	$0.35	$0.57	$0.93	$1.52	$2.48	$4.04	$6.58	$10.71
GCAM4	**US$2024/gallon**	**$2.14**	**$2.23**	**$2.23**	**$3.05**	**$3.50**	**$4.16**	**$5.18**	**$6.79**	**$9.35**	**$13.45**
SSP3-6.0	**Unit**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**	**2080**	**2090**	**2100**
GCAM4	US$2005/GJ	$10.56	$11.00	$11.53	$11.92	$12.01	$11.99	$11.88	$11.68	$11.47	$11.29
GCAM4	US$2005/t C02	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
GCAM4	**US$2024/gallon**	**$2.14**	**$2.23**	**$2.33**	**$2.41**	**$2.43**	**$2.43**	**$2.40**	**$2.36**	**$2.32**	**$2.29**

As detailed in Table 2, for both the low emission and high emission scenarios, the gasoline prices were initially in 2005 US dollars per gigajoule (US$2005/GJ). To update these figures, we converted them to 2024 US dollars and then to gallons. This conversion was achieved by multiplying the original figures by 7.59, representing the number of exajoules in a gallon. Following this conversion, we factored in the additional costs of the carbon tax to arrive at the final gasoline prices (Table 3).

Table 3. Final Gasoline Prices.

SSP1-2.6	Variable	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
GCAM4	Price| Secondary Energy | Electricity	$0.12	$0.13	$0.13	$0.14	$0.15	$0.15	$0.15	$0.13	$0.12	$0.11
GCAM4	Price | Carbon	$ -	$ -	$25.78	$42.00	$68.41	$111.43	$181.52	$295.67	$481.61	$784.50
GCAM4	Price | Carbon	$ -	$ -	$39.62	$64.53	$105.11	$171.22	$278.90	$454.30	$740.01	$1205.40
N/A	Carbon Intensity of the Electricity Mix	561.00	433.49	334.96	258.83	200.00	154.54	119.42	92.97	71.30	55.10

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[10] Data obtained from Github: GitHub - JGCRI/ssp-data: Results for the GCAM SSPs, as documented in https://doi.org/10.1016/j.gloenvcha.2016.06.010

[11] Riahi, K., D. P. van Vuuren, E. Kriegler, J. Edmonds, B. C. O'Neill, S. Fujimori, N. Bauer, K. Calvin, R. Dellink, O. Fricko, W. Lutz, A. Popp, J. C. Cuaresma, S. Kc, M. Leimbach, L. Jiang, T. Kram, S. Rao, J. Emmerling, K. Ebi, T. Hasegawa, P. Havlik, F. Humpenöder, L. A. Da Silva, S. Smith, E. Stehfest, V. Bosetti, J. Eom, D. Gernaat, T. Masui, J. Rogelj, J. Strefler, L. Drouet, V. Krey, G. Luderer, M. Harmsen, K. Takahashi, L. Baumstark, J. C. Doelman, M. Kainuma, Z. Klimont, G. Marangoni, H. Lotze-Campen, M. Obersteiner, A. Tabeau and M. Tavoni (2017). "The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview." Global Environmental Change 42: 153-168 retrieved from: The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview - ScienceDirect

N/A	Carbon Intensity of the Electricity Mix	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
N/A	Price | Carbon	$ -	$ -	$0.01	$0.02	$0.02	$0.03	$0.03	$0.04	$0.05	$0.07
N/A	**Price | Electricity + Cabon**	**$0.123**	**$0.128**	**$0.145**	**$0.160**	**$0.175**	**$0.181**	**$0.178**	**$0.174**	**$0.171**	**$0.171**
SSP3-6.0	**Variable**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**	**2080**	**2090**	**2100**
GCAM4	Price| Secondary Energy | Electricity	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.11	$0.11
GCAM4	Price | Carbon	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
N/A	**Price | Electricity + Cabon**	**$0.123**	**$0.123**	**$0.123**	**$0.121**	**$0.118**	**$0.118**	**$0.118**	**$0.115**	**$0.113**	**$0.111**

For the analysis of electricity prices, we used the same dataset from the GCAM as we did for gasoline. Similar to the gasoline data, this dataset did not include the SSP3-7.0 scenario. Therefore, we used a comparable scenario, SSP3-6.0, as a substitute. For both scenarios, the electricity prices were initially in 2005 US dollars per gigajoule (US$2005/GJ). These prices were then multiplied by 277.78 to convert them to US dollars per kilowatt-hour (US$2005/kWh). Subsequently, they were multiplied by 1.54 to convert the prices from 2005 US dollars to 2024 US dollars. To estimate the carbon tax per kWh, our team made assumptions about the carbon intensity of the electricity grid. [12]

For the carbon intensity of the electricity grid, data are available only for the SSP1-1.9 scenario. Consequently, the ICF team applied a more conservative reduction in grams of CO_2 equivalent per kWh to represent the SSP1-2.6 scenario. Under the SSP1-1.9 scenario, the carbon intensity of the electricity mix is projected to decrease linearly from 561 grams of CO_2 equivalent per kWh (g CO_2e/kWh) in 2010 to 50 g CO_2e/kWh by 2050. This reduction is attributed to a significant increase in renewable electricity generation, coupled with CO_2 capture and efficiency improvements in the remaining fossil-fueled power plants. The ICF team estimated that under the SSP1-2.6 scenario, the carbon intensity would decline from 561 g CO_2e/kWh in 2010 to 200 g CO_2e/kWh in 2050, and further to 55 g CO_2e/kWh by 2100. These figures were then converted from g CO_2e/kWh to tonnes of CO_2e/kWh by dividing by 1 million. The carbon price was calculated by multiplying the tonnes of CO_2e/kWh by US$2024 per tonnes of CO_2.

Interpolation of Gasoline and Electricity Data

ICF chose not to interpolate estimates from SSP3-6.0 to SSP3-7.0 for electricity and gasoline because the relationship of the given data did not provide reasonable estimates for SSP3-7.0 using methodology methods that we considered justifiable for our analysis. As such, for electricity and gasoline we only provide estimates for SSP1-2.6 and SSP3-6.0.

To obtain values for SSP1-2.6 and SSP3-6.0 for the chosen years for our analysis (2024, 2034, 2064, and 2104) we used linear interpolation. To interpolate values for 2104 for each scenario, since we did not have an upper bound value from the input data, we used a linear curve for the given price data from 2080-2100 using the FORECAST.LINEAR function in Excel.

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[12] Wolfram P, Hertwich EG. (2021) "Potential Climate Impact Variations Due to Fueling Behavior of Plug-in Hybrid Vehicle Owners in the US. Environ Sci Technol. 2021 Jan 5;55(1):65-72. doi: 10.1021/acs.est.0c03796. Epub 2020 Dec 16. PMID: 33327721; PMCID: PMC8277143. Retrieved from: Potential Climate Impact Variations Due to Fueling Behavior of Plug-in Hybrid Vehicle Owners in the US - PMC (nih.gov)

Population Data

Population data[13] are available for every 5 years from 2020-2100 for RCP 2.6 and RCP 7.0. To interpolate values for RCP 2.6 and 7.0 for each year from 2024-2104, we used an approach identical to that for gasoline and electricity.

Employed Population

To obtain the employed population for the analysis, we used the annual time series of population for both scenarios described in the previous section, along with national employment data from the Federal Reserve Economic Data (FRED) database.[14] ICF also used an estimate of the compound annual rate of change estimated by U.S. BLS based on projections of US employment from 2022 to 2032.[15] ICF applied this rate of change (0.3) to the level of employment in 2022 from FRED (158,296,500) to estimate the total U.S. employment for the year 2024. ICF estimated the employment level to be 159,184,487 using this method, which is shown in Table 4 below.

Table 4. Estimated Total U.S. Employment.

Year	Total estimated employment (number of employees)[a]
2024	159,184,487
Note 38. ICF estimated employment in 2024 using a compound annual rate of change of 0.3 percent from the FRED employment level in 2022 of 159,296,500 Source: Federal Reserve Economic Data (FRED) (2024). "Employment Level", CE16OV, retrieved fromhttps://fred.stlouisfed.org/series/CE16OV; U.S. Bureau of Labor Statistics (2023). "Employment Projections", table 2.1, retrieved from: https://www.bls.gov/emp/tables.htm; ICF analysis, 2024	

To obtain an annual time series from 2024-2104 of the employed U.S. population for SSP1-2.6, we first used the ratio of our estimated population for SSP1-2.6 for the year 2024, derived using the population methodology described in the previous section[16], and divided by the total estimated employment population for 2024 from Table 4 above. Using the formula below:

$$Pop\ SSP1\text{-}2.6_{\text{in year 2024}} / \ Estimated\ Employment\ Level_{\text{in year 2024}} = 347{,}677{,}993\ /\ 159{,}184{,}487 = 0.458$$

We then multiplied this ratio against every year of our annual time series of the total U.S. population for SSP1-2.6 to obtain an annual times series of the U.S. employed population under SSP1-2.6 from 2024 to 2104.

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[13] Samir KC, Wolfgang Lutz, (2014) "The human core of the shared socioeconomic pathways: Population scenarios by age, sex and level of education for all countries to 2100", Global Environmental Change, Volume 42, 2017, Pages 181-192,ISSN 0959-3780, DOI:10.1016/j.gloenvcha.2014.06.004

[14] Federal Reserve Economic Data (FRED) (2024). "Employment Level", CE16OV, retrieved from: https://fred.stlouisfed.org/series/CE16OV

[15] U.S. Bureau of Labor Statistics (2023). "Employment Projections", table 2.1, retrieved from: https://www.bls.gov/emp/tables.htm

[16] Samir KC, Wolfgang Lutz (2014). **"**The human core of the shared socioeconomic pathways: Population scenarios by age, sex and level of education for all countries to 2100", Global Environmental Change, Volume 42, 2017, Pages 181-192,ISSN 0959-3780, DOI:10.1016/j.gloenvcha.2014.06.004

To obtain an annual time series from 2024-2104 of the employed population for SSP3-7.0, we first took the ratio of our estimated population for SSP3-7.0 for the year 2024 and divided by the total estimated employment population for 2024 from Table 4. Using the formula below:

$$\textit{Pop SSP3-7.0}_{\textit{in year 2024}}/\ \textit{Estimated Employment Level}_{\textit{in year 2024}} = 333{,}153,\ 355\ /\ 159{,}184{,}487 = 0.478$$

We then took this ratio and multiplied it against every year of our annual time series of the total U.S. population for SSP3-7.0 to obtain an annual times series of the U.S. employed population under SSP3-7.0 from 2024 to 2104. The employed population for our analysis years for each scenario is shown in Table 5 below.

Table 5. Estimated Total U.S. Employment by Analysis Year (Number of Employees).

Year	Total estimated employment – SSP1-2.6	Total estimated employment – SSP3-7.0
2024	159,184,488	159,184,488
2034	171,212,859	161,780,729
2044	182,204,690	161,311,687
2064	201,386,355	153,917,302
2104	214,807,528	121,609,984

Climate Impacts to the Average American Basket of Goods

ICF collected national data from the US Census Bureau's American Community Survey (ACS) and the Bureau of Labor Statistics' (BLS) Consumer Expenditure Survey (CES) to define an illustrative baseline basket of consumer goods, by region and household composition. This subsection describes the basket of goods and the general approach for estimating the impacts of climate change on household expenditures.

We used the following main consumer categories: housing, transportation, energy and utilities, food, healthcare, entertainment, and an "other" catch all category. From the CES and ACS, detailed household consumer expenditure data were downloaded to determine the availability of household cost data. Within these main categories, our analysis does not comprehensively address all possible sub-categories, due to the lack of scientific analysis in some areas. Therefore, **our estimated changes in consumer costs are an underestimate, compared to if we had been able to assess climate change impacts to the entirety of consumers' purchases.**

Our approach to determining the defensible level of detail for individual sub-categories reported in the basket of goods is based on following criteria: (1) availability of scientific literature to provide sufficient data to estimate changes due to climate change, (2) availability of baseline cost data from the CES and ACS, and (3) availability of data or conversion factors to estimate the percentage change or direct dollar value change under the two specific climate change scenarios. Table 6 describes the initial basket goods and proposed methodology for quantitively and qualitatively assessing the impacts of climate change on the basket of goods. The sections below provide additional information for how each expenditure was derived as well as the supporting data and literature used in estimating the prices.

Table 6. Cost of Living Impact Estimation Process from Literature Review

Category	Approach	Data Sources

Food	Projected maize and wheat crop yields and resulting price increase	Zhao et al. (2017); Schnitkey and Paulson (2023); Lee (2023); Baker et al. (2018)
Housing	Projected property coastal and riverine flooding exposure and resulting damage costs	NFIP Claims and Policies 1985-2018; 2022 1-Year ACS; NOAA Billion-Dollar Flooding Events; Swain et al. (2020); Knutson et al. (2020)
Energy	Projected Cooling Degree Days (CCD)/Heating Degree Days (HDD) energy demand and cost multiplier	Jaglom et al. (2014); EPA (2023); EIA (2023)
Transportation	Projected vehicle crashes increase due to extreme weather and resulting costs	2022 1-Year ACS; NHTSA CRSS Dataset; NCS Economic Costs
Healthcare	Projected heat-related illness frequency and resulting costs	Jagai et al. (2017); EPA (2023)

According to the ACS, in the United States the average single person household spends $38,300 per year, while the average four-person household (two adults and two children) spend $91,300 per year.[17] While these averages provide a benchmark for understanding overall consumer expenditures, the cost of living and employment income vary significantly based upon the region a person lives in. Other factors impacting cost of living and consumption patterns include dependents, occupations, and whether a person lives in an urban, suburban, or rural setting. To address this, the consumer expenditure data were collected for the following household sizes: a single adult, single adult with children, two adults, and two adults with children. In addition, these data were collected for the US average and the following markets to highlight the regional variation and align with personas located in the following metropolitan areas: Boston, MA; Cedar Rapids, IA; Reno, NV; and Tampa FL.

Given the variety of expenditures encompassing services, manufactured goods, food, and utilities, additional research was needed to convert climate impact estimates for various industry sectors and commodities to the correct consumer units. The following expenditure sections provide information on the data and assumptions used for these conversions. Some general simplifying assumptions were made that apply to all estimates to capture the change in prices due to climate change to the average American households and to the personas with different household sizes, educational background, locations, and occupations. These key assumptions are:

- All changes in climate costs will be passed onto the consumer.
- Cost changes in the basket of goods only factor in the impact of climate change. Inflation is not captured and will make these goods even more expensive in future years.
- All costs were converted to 2024 dollars using the BEA GDP deflator data and CBO estimates for 2024. All dollar figures in this study were converted to constant 2024 dollars using the Bureau of Economic Analysis GDP Deflator data and Congressional Budget Office estimates for 2024. These adjustments were made so that all dollars are comparable and maintain the same purchasing

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[17] US Census Bureau, (2022). ACS 1-year Estimate, Tables B19109, B19119, and B19126. https://www.census.gov/programs-surveys/acs/technical-documentation/table-and-geography-changes/2022/1-year.html (Adjusted to 2024 dollars using the Bureau of Economic Analysis, GDP Deflators, Table 1.1.4. Price Indexes for Gross Domestic Product)

power over time. All cost, price, and dollar estimates in this study can be compared for any present or forecasted period without additional conversion.

- The results do not factor in debt and assume any excess income is available for more consumption or savings.
- Changes in consumer preferences, cultural shifts, productivity, tax policy, supply chain shortages, tariffs, inflation, interest rates, financing, and other unknown economic pressures that will impact prices in the future are not covered in our estimates of consumer prices. However, as described in a section below on net income, climate-driven changes in taxes and tariffs were separately estimated.

These calculations utilize aggregate data and apply the best available measures to ensure dollar concepts and other units are comparable so that the resulting estimates allow for “apples to apples” comparisons. The costs described capture the impacts of the two climate scenarios relative to costs in 2024. The following sections provide details on the calculations, results, and describe any uncertainty or shortcomings of the analysis.

Methodology for Food

Climate change disrupts the agricultural industry and is expected to reduce access to food and increase food prices.[18] Specifically, warmer temperatures, extreme weather events, and changes in precipitation patterns pose challenges to farmers and can interrupt the food supply causing consumers to face higher prices at checkout lanes.[19] The risks associated with climate change are greatest for low-income populations and for geographic regions at lower latitudes including the tropics and subtropics.[20] Although some regions might see positive effects from warming temperatures and increased carbon dioxide fertilization, climate models consistently predict that climate change will have a net negative effect on food production.[21] To monetize the negative effect of climate change for consumers, ICF leveraged existing studies, described below, to approximate how climate change is expected to increase the price of two core crops and an aggregate food measure.

Two Core Crops: Maize and Wheat

Together maize and wheat make up 40 percent of America’s crop production value.[22] Given their importance to America’s agriculture industry, numerous researchers have studied how climate change will affect crop yields.[23] To translate reduced yields to increased prices ICF first obtained estimates on

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[18] Bolster, Carl et al (2023). "Fifth National Climate Assessment" U.S. Global Change Research Program, Chapter 11: Agriculture, food systems, and rural communities, retrieved from: https://doi.org/10.7930/NCA5.2023.CH11.

[19] Bolster, Carl et al (2023). "Fifth National Climate Assessment" U.S. Global Change Research Program, Chapter 11: Agriculture, food systems, and rural communities, retrieved from: https://doi.org/10.7930/NCA5.2023.CH11.

[20] Brown, M.E. et al (2015). "Climate change, global good security and the U.S. food system" U.S. Global Change Research Program, retrieved from: https://www.usda.gov/sites/default/files/documents/FullAssessment.pdf.

[21] Brown, M.E. et al (2015). "Climate change, global good security and the U.S. food system" U.S. Global Change Research Program, retrieved from: https://www.usda.gov/sites/default/files/documents/FullAssessment.pdf.

[22] United States Department of Agriculture (2021). Quick Stats, Annual crop production values for 2021, retrieved from: https://quickstats.nass.usda.gov/.

[23] Deryng, Delphine et al (2014). "Global crop yield response to extreme heat stress under multiple climate change futures" Environmental Research Letters, retrieved from: https://iopscience.iop.org/article/10.1088/1748-9326/9/4/041001; Hultgren, Andrew et al (2022). "Estimating global impacts to agriculture from climate change accounting for adaptation" SSRN Electronic Journal, retrieved from: http://dx.doi.org/10.2139/ssrn.4222020; Perry,

how a 1˚C increase reduces yields from a 2017 study published by the National Academy of Sciences (see **Error! Reference source not found.Error! Reference source not found.**).[24] ICF then gathered yield, price, and revenue data (see Table 8) and multiplied the expected decline in corn and wheat yields due to a 1˚C temperature increase (estimates from Table 7) by yields in Table 8 to obtain new yield estimates if temperature increases by 1˚C. ICF multiplied the new yield estimates, that take into account the 1˚C temperature increase, by the price of the good in 2024 to calculate crop revenues if temperature increases by 1˚C. Assuming the full burden of reduced yield is passed to consumers through higher prices, ICF estimated the percentage increase in price using the percentage change in crop revenues between the revenues presented in Table 8 and estimated revenues under a 1 ˚C temperature increase (see Table 10). ICF finds that maize is the most vulnerable to climate change as a 1˚C temperature increase is expected to reduce yields by 10.3 percent, resulting in an 11.5 percent increase in price.

Table 7. Percentage Change in Yield from a 1˚ C Increase in Temperature in the United States.

Crop	Percent Change
Maize	-10.3%
Wheat	-5.5%
Source: Zhao, Chuang et al (2017). "Temperature increase reduces global yields of major crops in four independent estimates" Proceedings of the National Academy of Sciences, Figure 2A, retrieved from https://www.pnas.org/doi/full/10.1073/pnas.1701762114.	

Table 8. Yield, Price, and Revenue Data for Core Crops in 2024.

	Corn	Wheat
Yield	221	78
Price per bushel	$4.50	$6.80
Crop revenue	$995.00	$530.00
[a]Projected values Source: Schnitkey, Gary and Paulson, Nick (2023). "Revenue and Costs for Illinois Grain Crops" Farm Business Management, University of Illinois, Table 1 and 9, retrieved from: https://farmdoc.illinois.edu/handbook/historic-corn-soybeans-wheat-and-double-crop-soybeans.		

Aggregate Food Measure

A 2023 study from the European Central Bank provided a global estimate for the direct effect of climate change on food prices. ICF performed a set of calculations to convert that estimate in terms of a 1˚C

Edward et al (2020). "Using insurance data to quantify the multidimensional impacts of warming temperatures on yield risk" Nature Communications, retrieved from: https://www.nature.com/articles/s41467-020-17707-2; Schlenker, Wolfram and Roberts, Micheal (2008). "Estimating the Impact of Climate Change on Crop Yields: The Importance of Nonlinear Temperature Effects" National Bureau of Economic Research, retrieved from: https://www.nber.org/papers/w13799; and Zhao, Chuang et al (2017). "Temperature increase reduces global yields of major crops in four independent estimates" Proceedings of the National Academy of Sciences, Figure 2b, retrieved from: https://www.pnas.org/doi/full/10.1073/pnas.1701762114.

[24] Zhao, Chuang et al (2017). "Temperature increase reduces global yields of major crops in four independent estimates" Proceedings of the National Academy of Sciences, Figure 2b, retrieved from: https://www.pnas.org/doi/full/10.1073/pnas.1701762114. Note that temperature change is simply used as an indicator of the wide variety of changes in climate variables, including precipitation, that are used to adjust crop yields in the underlying studies.

temperature increase on price.[25] Specifically ICF utilized their estimate of the difference in food inflation under the RCP 2.6 and 8.5 climate scenarios in 2060 and climate scenario temperatures from the IPCC AR6 report (see Table 9) to determine how responsive aggregate food prices are to a 1˚C temperature increase. [26] Ultimately, ICF found that a 1˚C increase in temperature leads to a 3.1 percent increase in aggregate, global food prices (see Table 10). This global estimate likely understates the effect for countries in the global south, while overstating the effect for countries in the north, as southern countries are expected to feel the effects of climate change more acutely.[27] In the United States, Kotz et, al. (2023) estimated that the annual impact on food inflation by 2035 under RCP 8.5 is between 1.0% to 1.5%, whereas northern and southern countries will see a -0.5% to 1% or a 1.0% plus change in food inflation, respectively.[28] Given that the United States falls in the middle of these estimates, the global, averaged price effect is likely representative of the domestic price effect.

Table 9. Estimated Increase in Temperature by 2060.

Scenario	Increase in Temperature
Low Scenario	1.7 ˚ C
High Scenario	2.4 ˚ C
Source: Lee, Hoesung (2023). “Synthesis report of the IPCC sixth assessment report” Intergovernmental Panel on Climate Change, page 16, retrieved from: https://report.ipcc.ch/ar6syr/pdf/IPCC_AR6_SYR_LongerReport.pdf.	

Scaling Across Time and Climate Scenarios

ICF utilized estimated increases in price from a 1˚C increase in temperature (see Table 10) and the estimated temperature under the two climate scenarios at each time point (see Table 11) to scale our price estimates, assuming a linear relationship between price and temperature. The temperatures presented in Table 10 are normalized so the base year is 2024, instead of 1995 as shown in Table 1 of the report.

Table 10. Estimated Increase in Price from a 1˚C Increase in Temperature.

Crop	Percent Increase in Price
Maize	11.5%
Wheat	5.7%
Food Aggregate	3.1%

Table 11. Expected Temperature Increases Under Climate Scenarios (Relative to 2024).

Scenario	2034	2044	2064	2104
Low Scenario (SSP1-2.6)	0.37	0.64	0.85	0.76

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[25] Kotz, Maximilian et al (2023). "The impact of global warming on inflation: averages, seasonality and extremes" European Central Bank, page 16, retrieved from: http://dx.doi.org/10.2139/ssrn.4457821.

[26] Kotz, Maximilian et al (2023). "The impact of global warming on inflation: averages, seasonality and extremes" European Central Bank, page 16, retrieved from: http://dx.doi.org/10.2139/ssrn.4457821; and Lee, Hoesung (2023). "Synthesis report of the IPCC sixth assessment report" Intergovernmental Panel on Climate Change, page 16, retrieved from: https://report.ipcc.ch/ar6syr/pdf/IPCC_AR6_SYR_LongerReport.pdf.

[27] Kotz, Maximilian et al (2023). "The impact of global warming on inflation: averages, seasonality and extremes" European Central Bank, retrieved from: http://dx.doi.org/10.2139/ssrn.4457821.

[28] Kotz, Maximilian et al (2023). "The impact of global warming on inflation: averages, seasonality and extremes" European Central Bank, page 20, retrieved from: http://dx.doi.org/10.2139/ssrn.4457821.

High Scenario (SSP3-7.0)	0.47	0.93	1.88	4.27

Assumptions

Our price estimates rely on the assumption that there is a linear relationship between temperature and price. Although studies find that the effect of temperature on agriculture are more extreme at higher temperatures, data limitations restricted the flexibility of our estimates.[29] However, our estimates are relatively consistent with other studies that consider the non-linear impact of temperature on agriculture. For example, Baker et al (2018) estimated that the price of corn and wheat in the United States will increase by 23.6 and 17.1 percent, respectively averaged across numerous climate scenarios from 2010 to 2050.[30] Comparatively, using our methodology and averaging across four climate scenarios from 2010 to 2050 prices for maize, and wheat will increase by 20.5 and 10.2 percent, respectively. Although ICF expected some variation in estimates as Baker et al (2018) assumed base trade as well as non-linear impacts, the relative consistency strengthens the confidence that can be placed in the price estimates.

The price estimates for the two core crops depend on two additional assumptions:

1. Costs of production for farmers are fixed.
2. The entirety of the climate change burden is passed to the consumer.

ICF found literature that mitigated the concerns of these two assumptions. Specifically, ICF found that demand for food is relatively inelastic and that average farm production expenditures were static from 2014 to 2020.[31]

Quantitative Results

Table 12. Projected Percentage Increase in Maize Prices Driven by Climate Change Under the Low and High Climate Scenarios (Relative to 2024).

Scenario	2034	2044	2064	2104
Low Scenario (SSP1-2.6)	4.3%	7.4%	9.8%	8.8%
High Scenario (SSP3-7.0)	5.4%	10.8%	21.6%	49.2%

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[29] Kotz, Maximilian et al (2023). "The impact of global warming on inflation: averages, seasonality and extremes" European Central Bank, page 16, retrieved from: http://dx.doi.org/10.2139/ssrn.4457821; and Schlenker, Wolfram and Roberts, Micheal (2008). "Estimating the Impact of Climate Change on Crop Yields: The Importance of Nonlinear Temperature Effects" National Bureau of Economic Research, retrieved from: https://www.nber.org/papers/w13799.

[30] Baker, Justin et al (2018). "Evaluating the effects of climate change on US agricultural systems: sensitivity to regional impact and trade expansion scenarios" Environmental Research Letters, table 2, retrieved from: https://iopscience.iop.org/article/10.1088/1748-9326/aac1c2.

[31] Roberts, Micheal and Schlenker, Wolfram (2010). "Identifying supply and demand elasticities of agricultural commodities: implications for the us ethanol mandate" National Bureau of Economic Research, retrieved from: https://www.nber.org/system/files/working_papers/w15921/w15921.pdf.; and United States Department of Agriculture (2021). "Farm production expenditures 2020 summary" page 6, retrieved from: https://www.nass.usda.gov/Publications/Todays_Reports/reports/fpex0721.pdf.

Table 13. Projected Percentage Increase in Wheat Prices Driven by Climate Change Under the Low and High Climate Scenarios (Relative to 2024).

Scenario	2034	2044	2064	2104
Low Scenario (SSP1-2.6)	2.1%	3.7%	4.9%	4.4%
High Scenario (SSP3-7.0)	2.7%	5.4%	10.8%	24.5%

Table 14. Projected Percentage Increase in Aggregate Food Prices Driven by Climate Change Under the Low and High Climate Scenarios (Relative to 2024).

Scenario	2034	2044	2064	2104
Low Scenario (SSP1-2.6)	1.1%	2.0%	2.6%	2.3%
High Scenario (SSP3-7.0)	1.4%	2.9%	5.7%	13.0%

It's important to note that trade, advancements in agriculture technology, and industry policies, such as subsidies and tariffs, are not reflected in these estimates.

Quantitative Effects on Household Budgets

Table 15 displays how the price increases presented in Table 12, Table 13, and Table 14 will affect food expenditures for American households under the high and low climate scenarios. ICF used corn-specific estimates to calculate household expenditures on fruits and vegetables, wheat-specific estimates to calculate household expenditures on cereals and bakery products, and aggregate food estimates to calculate expenditures on all other food categories.

Table 15. Dollars Spent on Food by Scenario and Household Type – US (National) ($2024).

	Timeline				
Scenario	**2024**	**2034**	**2044**	**2064**	**2104**
	Single Adult				
Low Scenario (SSP1-2.6)	$4,569	$4,643	$4,696	$4,737	$4,719
High Scenario (SSP3-7.0)	$4,569	$4,662	$4,754	$4,938	$5,405
	Single Adult with Children[32]				
Low Scenario (SSP1-2.6)	$8,006	$8,133	$8,225	$8,298	$8,266
High Scenario (SSP3-7.0)	$8,006	$8,166	$8,326	$8,649	$9,470
	Two Adults				
Low Scenario (SSP1-2.6)	$7,982	$8,109	$8,200	$8,273	$8,241
High Scenario (SSP3-7.0)	$7,982	$8,142	$8,301	$8,621	$9,436
	Two Adults with Children				
Low Scenario (SSP1-2.6)	$12,059	$12,250	$12,388	$12,497	$12,449
High Scenario (SSP3-7.0)	$12,059	$12,299	$12,539	$13,022	$14,249

Note: Wheat was used as a proxy for cereals and bakery products and corn was used as a proxy for fruit and vegetable products, all other food categories were estimated using the aggregate food measure.

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[32] The Bureau of Labor Statistic's Consumer Expenditure Survey used to determine household spending on each basket item only provided estimates for "with" and "without" children. Based on the survey, the average number of children among single adults with children is 1.7 and the average number of children among two adults with children is 1.6.

Food currently represents approximately 13 percent of household expenditures and 11 percent of income on average. Therefore, changes in food prices will have a significant effect on consumer budgets. Under the two climate scenarios ICF estimates the following:

- Low climate scenario: food expenditures will increase by 3 percent by 2104.
- High climate scenario: food expenditures will increase by 18 percent by 2104.

The 15-percentage point difference in the change of expected food expenditures by 2104, underscores the importance of reducing greenhouse gas emissions. If America goes down the high scenario path, consumers will likely face financial challenges. But, if emissions are significantly reduced, per the low scenario, consumers will face much smaller price increases. The burden of climate change will disproportionately affect single adults with children. Specifically, under the high climate scenario single adults over 40 with children are expected to spend approximately 17-20 percent of their income on food.

Qualitative Effects

Due to data limitations, ICF had to rely on the aggregate food measure for food categories including meat, eggs, and dairy. However, researchers have discussed the effects of climate change on these goods. Multiple researchers predict that the catch potential for fish will decrease as the climate warms, leading to overall declines in fish production.[33] Additionally, as temperature increases, heat stress on animals is expected to increase.[34] St-Pierre (2003) estimated that between 1871 and 1932, average annual losses for dairy, beef and swine industries were $897 million, $369 million, $299 million, and $128 million, respectively.[35] Additionally, Key et al. (2014) estimated that climate change will cause production loss to almost all dairies and result in $62-$162 million in losses for consumers due to higher milk prices by 2030.[36] Ultimately, climate change is expected to negatively impact the agriculture industry, leading to reductions in production and increased prices for consumers.

Methodology for Housing Costs

Property Damage Impacts

The effects of climate change on homes across the United States are becoming increasingly apparent. As an abundance of scientific research has shown, climate change is fueling an uptick in extreme weather events, from destructive hurricanes that batter coastal communities to intense thunderstorms and flooding brought by deluges of rainfall. These climate change-exacerbated phenomena stand to pose great risks to both the structure and contents of people's homes. Structural damage will result in costs to reconstruct or refurbish homes and damage to homes' contents will result in costs to repurchase lost

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[33] Lee, Hoesung (2023). "Synthesis report of the IPCC sixth assessment report" Intergovernmental Panel on Climate Change, page 38, retrieved from: https://report.ipcc.ch/ar6syr/pdf/IPCC_AR6_SYR_LongerReport.pdf; Barbarossa, Valerio et al (2021). "Threats of global warming to the world's freshwater fishes" Nature Communications, retrieved from: https://www.nature.com/articles/s41467-021-21655-w; and Free, Chistopher et al (2019). "Impacts of historical warming on marine fisheries production" Science, retrieved from: https://www.science.org/doi/10.1126/science.aau1758.

[34] St-Pierre, N.R. et al (2003). "Economic losses from heat stress by US livestock industries" Journal of Dairy Science, retrieved from: https://www.sciencedirect.com/science/article/pii/S0022030203740405.

[35] St-Pierre, N.R. et al (2003). "Economic losses from heat stress by US livestock industries" Journal of Dairy Science, retrieved from: https://www.sciencedirect.com/science/article/pii/S0022030203740405.

[36] Key, Nigel et al (2014). "Climate change, heat stress, and U.S. dairy production" United States Department of Agriculture, retrieved from: https://www.ers.usda.gov/webdocs/publications/45279/49164_err175.pdf?v=4492.2.

household goods and appliances. This report characterizes these financial impacts of property damage through 2104 under two future climate scenarios.

This analysis focuses on two types of flooding as the main sources of residential property damage: coastal and inland flooding. Coastal flooding involves saltwater inundation along the US' coasts originating from extreme events such as hurricanes and tropical storms, as well as the relatively steady rise in sea level in most coastal U.S. locations. Coastal flooding impacts are typically more costly than inland flooding, as saltwater corrodes materials more severely. Inland flooding refers to the freshwater inundation of land areas away from coastal regions, caused by excessive rainfall and snow melt. This type of flooding impacts all regions of the United States. Therefore, the damage costs from inland flooding overlap with coastal damages for some of the geographies in this analysis (i.e., Tampa, FL, Philadelphia, PA, New York, NY, and Boston, MA).

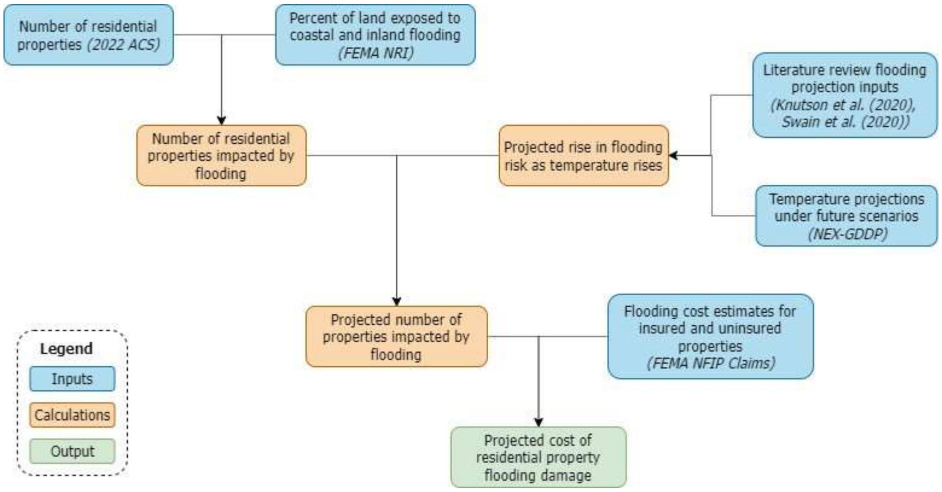

Figure 1. Diagram of Residential Property Damage Calculations.

Property damage estimates were derived from the combination of modeled flood risk, flood damage costs, and housing stock/value. Data from a variety of sources was incorporated to establish assumptions and estimate both baseline and projected levels of flooding risk, flooding costs, and number of properties impacted. Figure 1 illustrates how various data sources were incorporated into calculations to estimate the final damage costs incurred by an American consumer.

Flood Risk

The FEMA National Risk Index (NRI) is a comprehensive assessment tool designed to evaluate natural hazard risks by state across the United States, including flooding. The percentage of land exposed to either coastal or inland flooding was derived from the NRI by dividing the area (in square miles) at risk of each form of flooding by the total area for each state as well as nationally. This estimate is used as a proxy for the percentage of residential properties at risk of each type of flooding within each state relevant to the analysis. Table 16 presents these estimates.

Table 16. Baseline Land Exposure to Flooding: Proxy for Percent of Houses Impacted by Flooding.

Geography	Baseline Coastal Flooding Land Exposure	Baseline Inland Flooding Land Exposure
United States	0.060%	1.723%
Massachusetts	0.446%	0.647%
Iowa*	-	5.971%
New York	0.124%	0.867%
Pennsylvania	0.004%	0.949%
Nevada*	-	0.139%
Florida	1.051%	3.619%

*Iowa and Nevada have no risk of coastal flooding

Flooding risks are projected along future climate scenarios for the analysis periods from 2024 to 2104 using estimates of increased extreme weather frequency or severity. For coastal flooding projections, an estimate for the increase in the frequency of severe (category 4 and 5) tropical storms is taken from a meta analysis by Knutson et al. (2020). Knutson et al. (2020) calculate changes in tropical storm frequency globally by taking the median across modeled estimates from 11 peer reviewed studies. The median increase in global tropical storm frequency resulting from the meta analysis were extrapolated to the US context such that for every 1°F increase in temperatures, there will be a corresponding 4.2% increase in severe tropical storm frequency. This temperature-tropical storm relationship is modeled alongside projected temperature increases for SSP1-2.6 and SSP3-7.0 from 2034 to 2104 to estimate increases in coastal flooding nationally, using 2024 as the baseline. Table 17 presents coastal flooding risks for each year and scenario for the US.

Table 17. Projected Increase in Coastal Flooding Risk.

Scenario	Year	Temp Change from 2024	Increase in Coastal Flooding Events
SSP1-2.6	2034	0.37	1.5%
	2044	0.64	2.7%
	2064	0.85	3.5%
	2104	0.76	3.2%
SSP3-7.0	2034	0.47	1.9%
	2044	0.93	3.9%
	2064	1.88	7.8%
	2104	4.27	17.8%

For inland flooding, estimates on the change in population exposure to extreme freshwater flood potential due to climate change by state were adopted from Swain et al. (2020). Swain et al. (2020) combine simulations from a large climate model ensemble and a high-resolution hydrodynamic flood model to estimate the mean increase in a 100-year precipitation event and the resulting increase in population exposed to flooding for the years 2050 and 2080 and for both medium warming and high warming scenarios. The authors' estimates for medium and high warming scenarios were linearly extrapolated to fit this analysis' time frames from 2034 to 2104 for SSP1-2.4 and SSP3-7.0, respectively, compared to a 2024 baseline. Table 18 presents inland flooding risks for each year and scenario by state.

Table 18. Projected Increase in Inland Flooding Risk.

Scenario	Year	Increase in Inland Flooding Risk

		United States	MA	IA	NY	PA	NV	FL
SSP1-2.6	2034	14.8%	5.1%	33.4%	4.8%	1.6%	4.6%	13.0%
	2044	29.6%	10.2%	66.8%	9.5%	3.1%	9.1%	26.0%
	2064	44.4%	15.3%	100.3%	14.3%	4.7%	13.7%	39.0%
	2104	75.0%	14.5%	159.1%	26.5%	10.5%	21.4%	81.4%
SSP3-7.0	2034	15.4%	5.7%	34.0%	5.1%	1.7%	4.8%	13.6%
	2044	30.7%	11.4%	68.0%	10.3%	3.4%	9.6%	27.1%
	2064	46.1%	17.1%	102.0%	15.4%	5.0%	14.5%	40.7%
	2104	77.5%	16.6%	161.0%	27.9%	10.6%	23.1%	85.3%

Flood Damage Costs and Flood Insurance Coverage

Flood damage cost estimates were calculated using National Flood Insurance Program (NFIP) Claims data from 1985 to 2018. FEMA maintains a database of claims data with details on building type, flooding type, structural damage ($), contents damage ($), property value, contents value, and insurance deductibles. Data were filtered for residential properties and estimates for coastal versus inland flooding were delineated by filtering flood type accordingly. Damage costs were also distinguished between insured and uninsured properties. Dollar amounts were inflated to reflect costs in 2024 dollars and overall damage costs were averaged nationally. Table 19 presents these average percent estimated from the NFIP data of property value damaged due to flooding across NFIP. Insured properties were assumed to have a constant damage cost equal to the amount of their deductible for flood insurance, while uninsured properties were assumed to incur damages worth a percentage of their structural or contents value damaged due to flooding.

Table 19. Residential Property Flooding Costs, Uninsured vs. Insured Properties ($2024).

Proxy	Flood Type	Coastal Flooding	Inland Flooding
Uninsured Buildings	Average Building Damage (%)	27.4%	22.2%
Insured Buildings	Average of Building Deductible ($)	$961	$1,425
Uninsured Contents	Average Contents-to-Building Damage (%)	13.2%	11.4%
Insured contents	Average of Contents Deductible ($)	$847	$1,189

Similarly, flood insurance coverage was derived from current NFIP policies data for 2023. The percentage of flood insurance coverage by state was estimated by dividing the number of policies in force (PIF) by the number of residential properties by state. Data on the number of housing properties within each state was gathered from the 2022 American Community Survey (ACS). Table 20 presents these estimates.

Table 20. Property Counts and Flood Insurance Rates.

Geography	Housing Units	NFIP PIF	Flood Insurance Rate
United States	143,772,895	8,942,910	6.2%
Massachusetts	3,036,303	52,386	1.7%
Iowa	1,438,456	7,673	0.5%
New York	8,585,784	159,704	1.9%

Pennsylvania	5,815,191	38,808	0.7%
Nevada	1,328,788	9,106	0.7%
Florida	10,257,553	1,660,607	16.2%

These insurance rates were assumed to be consistent for each of the sub-state, targeted geographies in this analysis. Further data on the number of properties and the median housing value were gathered from the 2022 ACS and are presented alongside the insurance coverage in Table 21. As is shown in Table 19**Error! Reference source not found.**, flood damage costs were applied based on the split between insured and uninsured properties. The values for housing stock, housing value, flood insurance rates, and flooding costs were assumed to remain constant over the study period from 2024 to 2104.

Table 21. Property Counts and Median Values.

Geography	Housing Units	Median Housing Value	Uninsured Units
United States	143,772,895	$320,900	134,829,985
Boston, MA	2,064,220	$618,100	2,028,606
Cedar Rapids, IA	122,692	$195,100	122,038
New York, NY	8,074,003	$578,800	7,923,819
Philadelphia, PA	2,634,290	$332,600	2,616,710
Reno, NV	220,286	$528,900	218,776
Tampa, FL	1,512,833	$344,400	1,267,919

Residential Properties Impacted

The percent of properties impacted by coastal and inland flooding under each future climate scenario were derived by applying the increase in flooding risk estimates (Table 17 and Table 18) with the baseline flood risk levels (Table 16). These percentage estimates across the time periods of analysis were applied to the number of housing units in the target geographies, indicating how an increasing number of properties will be at risk of flooding as temperatures rise over time. These estimates are presented for coastal and inland flooding in Table 22 and Table 23, respectively.

Table 22. Coastal Flooding Number of Houses Impacted.

	Geography	United States	Mass.	Iowa	New York	Penn.	Nevada	Florida
Scenario	**Baseline (2024)**	151,462	13,537	-	10,668	213	-	107,809
SSP1-2.6	**2034**	153,795	13,745	-	10,833	216	-	109,470
	2044	155,496	13,897	-	10,952	218	-	110,681
	2064	156,835	14,017	-	11,047	220	-	111,634
	2104	156,254	13,965	-	11,006	219	-	111,220
SSP3-7.0	**2034**	154,409	13,800	-	10,876	217	-	109,907
	2044	157,359	14,064	-	11,084	221	-	112,007
	2064	163,299	14,595	-	11,502	229	-	116,235
	2104	178,389	15,944	-	12,565	250	-	126,976

Table 23. Inland Flooding Number of Houses Impacted.

	Geography	United States	Boston, MA	Cedar Rapids, IA	New York, NY	Phil., PA	Reno, NV	Tampa, FL
Scenario	**Baseline (2024)**	2,477,439	19,639	85,885	74,404	55,195	1,841	371,272
SSP1-2.6	**2034**	2,844,345	20,641	114,588	77,940	56,053	1,925	419,482
	2044	3,211,250	21,644	143,291	81,476	56,910	2,009	467,693
	2064	3,578,156	22,647	171,995	85,012	57,768	2,093	515,904
	2104	4,335,168	22,493	222,509	94,157	60,993	2,236	673,653
SSP3-7.0	**2034**	2,858,192	20,759	115,084	78,229	56,120	1,930	421,656
	2044	3,238,945	21,880	144,283	82,055	57,045	2,019	472,040
	2064	3,619,698	23,001	173,481	85,881	57,969	2,108	522,424
	2104	4,397,633	22,889	224,189	95,151	61,071	2,267	688,083

Damage Calculations

Overall property damage was calculated for insured and uninsured properties according to the insurance rates for each geography and the different damage cost estimates. For insured properties, damage costs were assumed to be equal to the total insurance deductible. For uninsured properties, damage costs were estimated by multiplying the damage factor (%) by the median housing value specific to each geography. Thus, total property damages for the number of properties impacted were summed for each geography. To make these costs applicable to the average consumer, the total property damage estimates were averaged across all properties in each geography to estimate the per-property damage costs that may be felt by all consumers. This was done for both insured and uninsured properties, as well as an overall damage across both types of properties, which serves as the final damage costs. Table 24 presents these results for SSP1-2.6 and SSP3-7.0. All damage amounts were estimated in 2024 dollars.

Table 24. Average Annual Property Flooding Damage Costs.

Scenario	Year	Geography	Coastal Flooding			Freshwater Flooding		
			Per Insured Property	Per Uninsured Property	Per Property Average	Per Insured Property	Per Uninsured Property	Per Property Average
SSP1-2.6	**Baseline (2024)**	United States	$0.97	$84	$79	$40	$1,988	$1,867
		Boston, MA	$10.48	$1,761	$1,731	$22	$2,114	$2,078
		Cedar Rapids, IA				$1,619	$49,100	$48,847
		New York, NY	$2.11	$332	$326	$21	$1,918	$1,882
		Philadelphia, PA	$0.13	$12	$12	$48	$2,505	$2,489
		Reno, NV				$19	$1,589	$1,579
		Tampa, FL	$113.92	$10,662	$8,954	$567	$30,387	$25,559
	2034	United States	$0.98	$86	$80	$46	$2,282	$2,143
		Boston, MA	$10.64	$1,788	$1,757	$23	$2,222	$2,184
		Cedar Rapids, IA				$2,160	$65,509	$65,171

		New York, NY	$2.14	$337	$331	$22	$2,009	$1,972
		Philadelphia, PA	$0.13	$12	$12	$49	$2,544	$2,528
		Reno, NV				$20	$1,662	$1,651
		Tampa, FL	$115.68	$10,826	$9,092	$641	$34,333	$28,878
	2044	United States	$0.99	$87	$81	$52	$2,577	$2,420
		Boston, MA	$10.76	$1,808	$1,777	$24	$2,330	$2,290
		Cedar Rapids, IA				$2,700	$81,919	$81,496
		New York, NY	$2.17	$341	$335	$23	$2,100	$2,061
		Philadelphia, PA	$0.13	$12	$12	$50	$2,583	$2,566
		Reno, NV				$21	$1,734	$1,723
		Tampa, FL	$116.95	$10,946	$9,193	$715	$38,279	$32,197
	2064	United States	$1.00	$87	$82	$58	$2,871	$2,696
		Boston, MA	$10.86	$1,823	$1,792	$25	$2,438	$2,396
		Cedar Rapids, IA				$3,241	$98,328	$97,821
		New York, NY	$2.19	$344	$338	$24	$2,191	$2,151
		Philadelphia, PA	$0.13	$12	$12	$51	$2,622	$2,605
		Reno, NV				$22	$1,807	$1,795
		Tampa, FL	$117.96	$11,040	$9,272	$789	$42,224	$35,516
	2104	United States	$1.00	$87	$82	$70	$3,479	$3,267
		Boston, MA	$10.81	$1,817	$1,785	$25	$2,421	$2,380
		Cedar Rapids, IA				$4,193	$127,207	$126,551
		New York, NY	$2.18	$343	$336	$27	$2,427	$2,382
		Philadelphia, PA	$0.13	$12	$12	$54	$2,769	$2,750
		Reno, NV				$23	$1,930	$1,917
		Tampa, FL	$110.13	$7,152	$6,012	$1,030	$55,135	$46,376
SSP3-7.0	**Baseline (2024)**	United States	$0.97	$84	$79	$40	$1,988	$1,867
		Boston, MA	$37.12	$1,761	$1,731	$22	$2,114	$2,078
		Cedar Rapids, IA				$1,619	$49,100	$48,847
		New York, NY	$9.19	$332	$326	$21	$1,918	$1,882
		Philadelphia, PA	$24.79	$12	$12	$48	$2,505	$2,489
		Reno, NV				$19	$1,589	$1,579
		Tampa, FL	$103.60	$10,662	$8,953	$567	$30,387	$25,559
	2034	United States	$0.99	$86	$81	$46	$2,294	$2,154
		Boston, MA	$37.85	$1,795	$1,765	$23	$2,235	$2,197
		Cedar Rapids, IA				$2,169	$65,793	$65,453
		New York, NY	$9.37	$339	$333	$22	$2,016	$1,979
		Philadelphia, PA	$25.28	$12	$12	$49	$2,547	$2,531
		Reno, NV				$20	$1,666	$1,655

		Tampa, FL	$105.61	$10,869	$9,127	$644	$34,511	$29,028
	2044	United States	$1.00	$88	$82	$52	$2,599	$2,441
		Boston, MA	$38.57	$1,829	$1,799	$25	$2,355	$2,315
		Cedar Rapids, IA				$2,719	$82,486	$82,060
		New York, NY	$9.55	$345	$339	$23	$2,115	$2,076
		Philadelphia, PA	$25.76	$12	$12	$50	$2,589	$2,572
		Reno, NV				$21	$1,743	$1,731
		Tampa, FL	$107.63	$11,077	$9,301	$721	$38,634	$32,497
	2064	United States	$1.04	$91	$85	$58	$2,905	$2,728
		Boston, MA	$40.03	$1,899	$1,866	$26	$2,476	$2,434
		Cedar Rapids, IA				$3,269	$99,178	$98,667
		New York, NY	$9.91	$358	$352	$25	$2,213	$2,173
		Philadelphia, PA	$26.73	$13	$13	$51	$2,631	$2,614
		Reno, NV				$22	$1,819	$1,807
		Tampa, FL	$111.69	$11,495	$9,652	$798	$42,758	$35,965
	2104	United States	$1.14	$99	$93	$71	$3,529	$3,314
		Boston, MA	$43.72	$2,074	$2,039	$26	$2,464	$2,422
		Cedar Rapids, IA				$4,225	$128,167	$127,506
		New York, NY	$10.82	$391	$384	$27	$2,452	$2,407
		Philadelphia, PA	$29.20	$14	$14	$54	$2,772	$2,754
		Reno, NV				$24	$1,957	$1,944
		Tampa, FL	$122.01	$12,557	$10,544	$1,052	$56,317	$47,370

Table 25 presents the summary of overall per-property damages across climate scenarios, years, and geographies.

Table 25. Summary of Property Damage Estimates.

Year	Geography	Per Property Damages (SSP1-2.6)	Per Property Damages (SSP3-7.0)
2034	United States	$2,224	$2,234
	Boston, MA	$3,942	$3,961
	Cedar Rapids, IA	$65,171	$65,453
	New York, NY	$2,303	$2,312
	Philadelphia, PA	$2,539	$2,543
	Reno, NV	$1,651	$1,655
	Tampa, FL	$37,971	$38,155
2044	United States	$2,501	$2,523
	Boston, MA	$4,067	$4,114

	Cedar Rapids, IA	$81,496	$82,060
	New York, NY	$2,396	$2,415
	Philadelphia, PA	$2,578	$2,585
	Reno, NV	$1,723	$1,731
	Tampa, FL	$41,390	$41,798
2064	United States	$2,778	$2,813
	Boston, MA	$4,188	$4,300
	Cedar Rapids, IA	$97,821	$98,667
	New York, NY	$2,488	$2,524
	Philadelphia, PA	$2,617	$2,627
	Reno, NV	$1,795	$1,807
	Tampa, FL	$44,788	$45,618
2104	United States	$3,348	$3,407
	Boston, MA	$4,166	$4,461
	Cedar Rapids, IA	$126,551	$127,506
	New York, NY	$2,718	$2,791
	Philadelphia, PA	$2,762	$2,768
	Reno, NV	$1,917	$1,944
	Tampa, FL	$52,388	$57,914

To validate the national-level results, ICF compared its estimates to Neumann et al. (2021)'s estimates of coastal property damage.[37] Neumann et al. estimate roughly $44 billion in total annual coastal property impacts in 2090 (estimating structural damages from flooding and costs of elevation/protection) under a high emissions scenario SSP5-8.5. Averaged over the number of coastal properties in the United States (roughly 36 million based on US Census data), average annual damage per costal property amounts to about $1,200.[38] ICF estimates both inland and coastal flooding damages per housing unit at an annual average of about $3,400 by 2104 under the high emissions scenario SSP5-8.5. The estimates ICF developed are approximately in line with the estimate by Neumann et al., although a degree of uncertainty remains.

Methodology for Vehicle Costs

Road travel may become even riskier for American drivers as climate change intensifies storms in the coming decades. Scientific research has found clear links between precipitation levels and vehicle crash rates—with heavier rainfall correlated to a higher likelihood of hazardous conditions and accidents. As climate change accelerates the Earth's water cycle and extreme weather, drivers around the country may need to brace for more crashes and the costs that come with them. This analysis digests data on crash statistics, vehicle ownership, precipitation-crash risk rates, and projected increases in precipitation

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[37] Neumann, J. E., Chinowsky, P., Helman, J., Black, M., Fant, C., Strzepek, K., & Martinich, J. (2021). "Climate effects on US infrastructure: the economics of adaptation for rail, roads, and coastal development". *Climatic change*, 167(3-4), 44.

[38] U.S. Census Bureau. (2023) "Emergency Management Areas" Retrieved from: https://www.census.gov/topics/preparedness/about/coastal-areas.html.

to estimate the cost to American consumers as crashes may become more frequent. Our analysis does not explicitly take into account other climate change-related costs that may be associated with vehicular travel, including the higher cost of gasoline that could be expected under a low climate scenario, the cost of transitioning to electric vehicles, etc.

Precipitation-Crash Risk Rates

Prior scientific research has found that there exists a causal relationship between varying levels of precipitation and the increased risk of vehicle accidents. For example, Black et al. (2017) use historical daily gridded precipitation data and automobile crash data from 1996 to 2010 to conduct a matched pair analysis to pair rainfall days with dry days to determine the relative risk of crash. The authors find that there is a statistically significant increase in crash rates during rainfall days and that these rates vary by the amount of rainfall. Table 26 summarizes Black et al. (2017)'s findings on increases in crash risks at different precipitation levels. This analysis adopts the authors' estimate for increased risk on days where precipitation is at or exceeds 12.5 mm.

Table 26. Increased Likelihood of Vehicle Crashes at Differing Rainfall Levels.

Rainfall	Increased Likelihood of Vehicle Crashes
≥ 12.5 mm	25.6%
≥ 25 mm	26.1%
≥ 50 mm	38.2%

Using projected estimates of the change in annual number of days with precipitation levels at or above 12.5 mm, the risk rate of 25.6% is applied to calculate the daily likelihood of vehicle crashes in future years and in different future climate scenarios due to projected increases in precipitation frequency and severity. The change in annual days is benchmarked against 2024 levels, so that the increases in risk start from 2024 onwards. The number of days with precipitation greater than or equal to 12.5 mm as well as the derived increased risk of vehicle crashes are presented in Table 27 below.

Table 27. Annual Precipitation and Daily Vehicle Crash Risk Projections.

Year	Additional annual days with ≥ 12.5 mm precipitation		Daily Risk of Vehicle Crashes	
	SSP1-2.6	SSP3-7.0	SSP1-2.6	SSP3-7.0
2034	0.13	0.14	3.3%	3.6%
2044	0.25	0.29	6.4%	7.4%
2064	0.43	0.6	11.0%	15.3%
2104	0.63	1.27	16.1%	32.5%

Vehicle Population Statistics

To estimate the relative impact on the average American consumer, data on the number of individuals with access to vehicles as well as the number of vehicles registered in each state were collected from the 2022 ACS. The ACS contains household-level data on the number of households with vehicles available by number of vehicles. Using the ACS data, the number of occupants and vehicles potentially impacted by increased crashes numbers are estimated so that crash costs for injury versus property damage crashes may be assessed separately. To estimate population-level estimates, i.e., the number of potential vehicle occupants, an average household size of 2.5 persons was multiplied to the household estimates. To estimate vehicle-level estimates, the number of vehicles available (presented by the ACS as one to four vehicles per household) were multiplied by the corresponding number of households. The results of the occupant and vehicle estimates are presented below (Table 28).

Table 28. Vehicle and Occupant Population Estimates.

Geography	Households with Vehicles Available	Number of Occupants	Number of Vehicles
United States	119,130,346	297,825,865	232,623,639
Florida	8,299,124	20,747,810	15,054,848
Iowa	1,256,452	3,141,130	2,586,528
Massachusetts	2,468,414	6,171,035	4,526,740
Nevada	1,113,962	2,784,905	2,157,648
New York	5,511,910	13,779,775	9,538,888
Pennsylvania	4,738,988	11,847,470	8,904,187

Vehicle Crashes

Summary data from the National Highway Traffic Safety Administration (NHTSA)'s 2021 Crash Report Sampling System (CRSS) dataset were gathered to estimate the number of motor vehicle injury only and property damage only (PDO) crashes by state. While crash counts for fatal crashes are available, this type of crash was omitted from this analysis as it is not relevant to estimating impacts on consumer expenditures. However, excluding the cost of fatal crashes, which are estimate based on value of statistical life (VOL) estimates at roughly $2 million per fatal crash ($2024), results in underestimates of the true cost of increased crashes due to climate change. The CRSS is a sample dataset that estimates the number of crashes across the country from a sample of representative crashes. As such, it does not represent actualized population values. As more granular data at the county or metropolitan statistics area (MSA) level were unavailable, this analysis relies on state-level estimates to serve as proxies for the more target geographies assessed throughout the report. The crash counts from the CRSS for the states relevant to the analysis are presented in Table 29 below.

Table 29. CRSS Crash Statistics by State.

State	Injury	PDO
Florida	150,906	378,731
Iowa	14,387	36,106
Massachusetts	17,360	43,569
Nevada	15,742	39,508
New York	48,057	120,610
Pennsylvania	50,418	126,536
United States	1,727,608	4,335,820

Using the projected daily vehicle crash rates derived in Table 27, the number of injury and PO crashes are projected for this analysis' period of analysis to 2104 under the two climate scenarios by state. These estimates are presented in Table 30 below.

Table 30. Projected Number Vehicle Crashes by State.

Year	Geography	Injury Crashes		Property Damage Only Crashes	
		SSP1-2.6	SSP3-7.0	SSP1-2.6	SSP3-7.0
2034	Florida	5,016	5,402	12,589	13,558
	Iowa	478	515	1,200	1,293
	Massachusetts	577	621	1,448	1,560
	Nevada	523	564	1,313	1,414
	New York	1,597	1,720	4,009	4,318
	Pennsylvania	1,676	1,805	4,206	4,530
	United States	57,427	61,845	144,127	155,214
2044	Florida	9,647	11,190	24,210	28,084
	Iowa	920	1,067	2,308	2,677
	Massachusetts	1,110	1,287	2,785	3,231
	Nevada	1,006	1,167	2,526	2,930
	New York	3,072	3,564	7,710	8,944
	Pennsylvania	3,223	3,739	8,089	9,383
	United States	110,437	128,107	277,167	321,514
2064	Florida	16,592	23,152	41,642	58,105
	Iowa	1,582	2,207	3,970	5,539
	Massachusetts	1,909	2,663	4,790	6,684
	Nevada	1,731	2,415	4,344	6,061
	New York	5,284	7,373	13,261	18,504
	Pennsylvania	5,544	7,735	13,913	19,413
	United States	189,952	265,050	476,728	665,202
2104	Florida	24,310	49,005	61,010	122,989
	Iowa	2,318	4,672	5,816	11,725
	Massachusetts	2,797	5,637	7,019	14,149
	Nevada	2,536	5,112	6,364	12,830
	New York	7,742	15,606	19,429	39,167
	Pennsylvania	8,122	16,373	20,384	41,091
	United States	278,302	561,022	698,462	1,408,010

Crash Cost Calculations

The National Safety Council (NSC) estimates average costs of vehicle accidents. The costs of injury or PDO crashes are a measure of the dollars spent and income not received due to injuries, including wage and productivity losses, medical expenses, administrative expenses, motor-vehicle damage, and employers' uninsured costs. Table 31 below presents the NSC's estimates of per-occupant and per-vehicle average economic costs of crashes used in this analysis inflated to 2024 dollars. While likely to occur, more severe injury types, such as evident injuries and disabling injuries were omitted from this analysis as the number of projected crashes may be an overestimate as adaptation efforts such as improved vehicle safety technology were not accounted for.

Table 31. Average Economic Crash Cost by Injury Severity ($2024).

Impact Type	Cost
Possible Injury (per occupant)	$27,120
Property damage only (per vehicle)	$6,441

Using the NSC per-crash cost estimates, the total cost impact of projected crashes may be calculated for both injury crashes and property damage crashes. Similarly, to make the crash costs meaningful to consumers, per-capita cost estimates were derived by dividing the total crash costs by the population of occupants and vehicles. These results are shown in Table 32 and Table 33 for injury crashes and PDO crashes, respectively.

Table 32. Projected Injury Crash Cost ($2024).

Year	Geography	Occupants Impacted		Injury Costs		Injury Cost Per Capita	
		SSP1-2.6	SSP3-7.0	SSP1-2.6	SSP3-7.0	SSP1-2.6	SSP3-7.0
2034	Florida	8,377	9,022	$227,187,984	$244,663,983	$10.95	$11.79
	Iowa	799	860	$21,658,895	$23,324,964	$6.90	$7.43
	Massachusetts	964	1,038	$26,135,506	$28,145,929	$4.24	$4.56
	Nevada	874	941	$23,699,703	$25,522,757	$8.51	$9.16
	New York	2,668	2,873	$72,349,926	$77,915,305	$5.25	$5.65
	Pennsylvania	2,799	3,014	$75,904,881	$81,743,718	$6.41	$6.90
	United States	95,904	103,281	$2,600,910,711	$2,800,980,765	$8.73	$9.40
2044	Florida	16,110	18,687	$436,899,969	$506,803,964	$21.06	$24.43
	Iowa	1,536	1,782	$41,651,721	$48,315,997	$13.26	$15.38
	Massachusetts	1,853	2,150	$50,260,588	$58,302,282	$8.14	$9.45
	Nevada	1,681	1,949	$45,576,351	$52,868,568	$16.37	$18.98
	New York	5,130	5,951	$139,134,473	$161,395,988	$10.10	$11.71
	Pennsylvania	5,382	6,244	$145,970,926	$169,326,274	$12.32	$14.29
	United States	184,430	213,939	$5,001,751,367	$5,802,031,586	$16.79	$19.48
2064	Florida	27,709	38,664	$751,467,946	$1,048,559,925	$36.22	$50.54
	Iowa	2,642	3,686	$71,640,960	$99,964,131	$22.81	$31.82
	Massachusetts	3,188	4,448	$86,448,211	$120,625,410	$14.01	$19.55
	Nevada	2,891	4,033	$78,391,324	$109,383,243	$28.15	$39.28
	New York	8,824	12,313	$239,311,293	$333,922,735	$17.37	$24.23
	Pennsylvania	9,258	12,918	$251,069,992	$350,330,221	$21.19	$29.57
	United States	317,220	442,633	$8,603,012,351	$12,004,203,281	$28.89	$40.31
2104	Florida	40,597	81,838	$1,100,987,921	$2,219,451,841	$53.07	$106.97
	Iowa	3,870	7,802	$104,962,337	$211,590,744	$33.42	$67.36
	Massachusetts	4,670	9,415	$126,656,681	$255,323,785	$20.52	$41.37
	Nevada	4,235	8,537	$114,852,406	$231,527,865	$41.24	$83.14
	New York	12,928	26,062	$350,618,872	$706,803,122	$25.44	$51.29
	Pennsylvania	13,564	27,343	$367,846,732	$741,532,302	$31.05	$62.59
	United States	464,765	936,906	$12,604,413,445	$25,408,896,944	$42.32	$85.31

Table 33. Projected PDO Crash Cost ($2024).

Year	Geography	Vehicles Impacted		Property Damage Costs		Damage Cost Per Capita	
		SSP1-2.6	SSP3-7.0	SSP1-2.6	SSP3-7.0	SSP1-2.6	SSP3-7.0
2034	Florida	12,589	13,558	$81,088,364	$87,325,930	$5.39	$5.80
	Iowa	1,200	1,293	$7,730,534	$8,325,190	$2.99	$3.22
	Massachusetts	1,448	1,560	$9,328,334	$10,045,898	$2.06	$2.22
	Nevada	1,313	1,414	$8,458,943	$9,109,631	$3.92	$4.22
	New York	4,009	4,318	$25,823,272	$27,809,678	$2.71	$2.92
	Pennsylvania	4,206	4,530	$27,092,113	$29,176,122	$3.04	$3.28
	United States	144,127	155,214	$928,321,959	$999,731,341	$3.99	$4.30
2044	Florida	24,210	28,084	$155,939,161	$180,889,427	$10.36	$12.02
	Iowa	2,308	2,677	$14,866,411	$17,245,037	$5.75	$6.67
	Massachusetts	2,785	3,231	$17,939,104	$20,809,360	$3.96	$4.60
	Nevada	2,526	2,930	$16,267,197	$18,869,949	$7.54	$8.75
	New York	7,710	8,944	$49,660,139	$57,605,761	$5.21	$6.04
	Pennsylvania	8,089	9,383	$52,100,218	$60,436,253	$5.85	$6.79
	United States	277,167	321,514	$1,785,234,537	$2,070,872,063	$7.67	$8.90
2064	Florida	41,642	58,105	$268,215,358	$374,253,987	$17.82	$24.86
	Iowa	3,970	5,539	$25,570,227	$35,679,386	$9.89	$13.79
	Massachusetts	4,790	6,684	$30,855,258	$43,053,849	$6.82	$9.51
	Nevada	4,344	6,061	$27,979,579	$39,041,274	$12.97	$18.09
	New York	13,261	18,504	$85,415,438	$119,184,333	$8.95	$12.49
	Pennsylvania	13,913	19,413	$89,612,375	$125,040,524	$10.06	$14.04
	United States	476,728	665,202	$3,070,603,404	$4,284,562,890	$13.20	$18.42
2104	Florida	61,010	122,989	$392,966,687	$792,170,940	$26.10	$52.62
	Iowa	5,816	11,725	$37,463,356	$75,521,367	$14.48	$29.20
	Massachusetts	7,019	14,149	$45,206,541	$91,130,647	$9.99	$20.13
	Nevada	6,364	12,830	$40,993,337	$82,637,363	$19.00	$38.30
	New York	19,429	39,167	$125,143,549	$252,273,504	$13.12	$26.45
	Pennsylvania	20,384	41,091	$131,292,550	$264,669,109	$14.75	$29.72
	United States	698,462	1,408,010	$4,498,791,034	$9,068,991,450	$19.34	$38.99

Table 34 below presents the total per-capita vehicle crash costs. These normalized totals intend to estimate the burden the average American consumer may experience across time as climate change impact road safety. However, it is important to note that per-crash costs are higher than the estimates presented below, and if a consumer were to get into an accident, their costs would likely be higher than the costs presented in Table 31.

Table 34. Projected Total Crash Cost ($2024).

Year	Geography	Total Vehicle Crash Costs Per Capita	
		SSP1-2.6	SSP3-7.0
2034	Florida	$16.34	$17.59
	Iowa	$9.88	$10.64
	Massachusetts	$6.30	$6.78
	Nevada	$12.43	$13.39
	New York	$7.96	$8.57
	Pennsylvania	$9.45	$10.18
	United States	$12.72	$13.70
2044	Florida	$31.42	$36.44
	Iowa	$19.01	$22.05
	Massachusetts	$12.11	$14.04
	Nevada	$23.90	$27.73
	New York	$15.30	$17.75
	Pennsylvania	$18.17	$21.08
	United States	$24.47	$28.38
2064	Florida	$54.04	$75.40
	Iowa	$32.69	$45.62
	Massachusetts	$20.82	$29.06
	Nevada	$41.12	$57.37
	New York	$26.32	$36.73
	Pennsylvania	$31.26	$43.61
	United States	$42.09	$58.72
2104	Florida	$79.17	$159.59
	Iowa	$47.90	$96.56
	Massachusetts	$30.51	$61.51
	Nevada	$60.24	$121.44
	New York	$38.56	$77.74
	Pennsylvania	$45.79	$92.31
	United States	$61.66	$124.30

Methodology for Healthcare Impacts: Heat-related Illness and Respiratory Illness

As climate change continues to warm the planet, the rate of some health conditions, specifically related to extreme heat and air quality are likely to increase.[39] While we did research both health insurance and

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[39] United States Environmental Protection Agency [EPA] (2023). "Climate Change and Children's Health and Well-Being in the United States", Page 35, retrieved from: Climate Change and Children's Health and Well-Being in the United States (epa.gov); Wondmegegn, Berhanu et al (2019). "What do we know about the healthcare costs of extreme heat exposure? A comprehensive literature review." Science of the Total Environment, page 609, retrieved from: What do we know about the healthcare costs of extreme heat exposure? A comprehensive literature review - ScienceDirect

healthcare, there is little to no empirical information relating climate change to an increase in the cost of health insurance premiums. The increasing number of extremely warm days in the United States presents an increasing risk of heat-related illness (HRI), such as heatstroke.[40]Additionally, the increased levels of PM2.5 and O_3 exposure are associated with an increase in new asthma diagnoses, especially in children.

In this analysis we focus on HRI and respiratory illness as two illustrative health impacts, amongst the many ways in which climate change may affect health. Our quantitative estimates do not include increased costs associated with other impacts including changes in infectious disease incidence[41], the mental health burden associated with climate change[42], or changes in injury rates associated with climate change-induced increases in storminess, flooding, and wildfire. The Environmental Protection Agency presents evidence that extreme heat has a negative impact on childhood learning, as increased temperature is associated with decreased cognitive function. This loss of learning could also impact earnings in the future.

Scaling Estimates Across Time and Climate Scenarios

Our analysis of HRI and respiratory illness requires that we scale our estimate across both time and climate scenarios. Estimates were developed for the years 2024, 2034, 2064, and 2104 and climate scenarios SSP1-2.6 and SSP3-7.0 (Table 35). Due to differences in data types for each of the health conditions analyzed, the scaling process differed across conditions. The following sections detail the assumptions required to estimate the health costs of climate change.

Table 35. Projected Temperatures Used for Scaling of Climate Scenarios.

Scenario	2024	2034	2044	2064	2100	2104
Low Scenario (SSP1-2.6)	1.26	1.64	1.91	2.12	2.03	2.03
High Scenario (SSP3-7.0)	1.19	1.66	2.13	3.07	4.11	5.46

Heat-related illness

Data are available that estimate the increase of the incidences of heat-related illness hospitalizations for every 1°C increase in monthly maximum temperature for the months May-September.[43] The increased rate for rural residents is 0.34 per 100,000 people for every degree increase, while the rate for urban residents is 0.02 per 100,000 for every degree increase. We multiplied the increased rates by the projected increase in temperature to determine the potential increase in rates of heat-related illness.

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[40] Wondmegegn, Berhanu et al (2019). "What do we know about the healthcare costs of extreme heat exposure? A comprehensive literature review." Science of the Total Environment, page 609, retrieved from: What do we know about the healthcare costs of extreme heat exposure? A comprehensive literature review - ScienceDirect

[41] Ebi, K., Hess, J., and Watkiss, P., 2017. Health Risks and Costs of Climate Variability and Change. In: Mock CN, Nugent R, Kobusingye O, et al., editors. *Injury Prevention and Environmental Health*. 3rd edition. Washington (DC): The International Bank for Reconstruction and Development / The World Bank; 2017 Oct 27. Chapter 8. doi: 10.1596/978-1-4648-0522-6_ch8

[42] Belova, A., Gould, C., Munson, K., Howell, M., Trevisan, C., Obradovich, N., and Martinich, J., 2022. Projecting the Suicide Burden of Climate Change in the United States. *Geohealth*. https://doi.org/10.1029/2021GH000580

[43] Jagai, Jyotsna et al (2017). "Hospitalization for heat-stress illness varies between rural and urban areas: an analysis of Illinois data, 1987-2014." Environmental Health, page 6, retrieved from: Hospitalizations for heat-stress illness varies between rural and urban areas: an analysis of Illinois data, 1987–2014 | Environmental Health | Full Text (biomedcentral.com)

This process was repeated for each year and climate scenario, in addition to both urban and rural scenarios. Below is an example of the formulas used:

Increased rate in HRI for rural residents =

(observed increase in HRI from 1°C) x (projected increase in temperature under SSP3-7.0)

Although we are assuming that the 1°C increase in monthly maximum temperature translates to annual temperature increases, we are still able to get a sense of the rates of increase of HRI due to more extreme temperatures for the summer months.

After estimating the increased rates of HRI hospitalizations, we compared them to the baseline of 1.8 HRI hospitalizations per 100,000 people to further understand the direct impact that climate change will have.

To determine the cost of heat-related illness, we used data on the average length of stay in the hospital for HRI and data for per-day cost of hospitalization. While HRI is not a lifetime affliction, we estimated the average annual increased likelihood of HRI cases for individuals residing in rural and urban settings and its associated impacts to healthcare costs.

Respiratory Illness

The increased rates of respiratory illness were calculated using data from the EPA's "Climate Change and Children's Health and Well-Being in the United States."[44] Those data provide the projected increase in number of cases for a 2°C warming scenario and a 4°C warming scenario, along with the current number of new respiratory illness diagnoses annually. We interpolated the increase in number of cases for the climate and time scenarios listed in Table 25. These estimations provide the information to calculate the percentage increase in new diagnoses of respiratory illness associated with PM2.5 and O_3 changes caused by climate change. Although these data are specific to children, the EPA paper also includes the lifetime cost for the medical expenses and lost productivity of respiratory illness.[45]

Results

The results for both HRI and respiratory illness show an increase in case rates and case numbers as global temperatures rise. The likelihood of having an HRI at some point during an individual's lifetime increases far more dramatically than the likelihood of being diagnosed with a respiratory illness as climate change becomes more extreme.

Heat-related illness

The below tables (Table 36 and Table 37) describe the increased rates of HRI due to climate change and increased temperatures from a 2024 baseline.

Table 36. Increase in Rate of HRI Hospitalizations from Baseline.

	Reported years	2034	2044	2064	2104

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[44] United States Environmental Protection Agency [EPA] (2023). "Climate Change and Children's Health and Well-Being in the United States", Page 35, retrieved from: Climate Change and Children's Health and Well-Being in the United States (epa.gov)

[45] United States Environmental Protection Agency [EPA] (2023). "Climate Change and Children's Health and Well-Being in the United States", Page 35, retrieved from: Climate Change and Children's Health and Well-Being in the United States (epa.gov)

Rural	Low Scenario (SSP1-2.6)	0.2262	0.3911	0.5211	0.4647
	High Scenario (SSP3-7.0)	0.2858	0.5719	1.1479	2.6112
Urban	Low Scenario (SSP1-2.6)	0.0133	0.0230	0.0307	0.0273
	High Scenario (SSP3-7.0)	0.0168	0.0336	0.0675	0.1536

Note: Baseline is 1.8 HRI related hospitalizations per 100,000 people.[46]

Table 37. Percentage Increase in Rate of HRI Hospitalization from Baseline.

	Reported years	**2034**	**2044**	**2064**	**2104**
Rural	Low Scenario (SSP1-2.6)	13%	22%	29%	26%
	High Scenario (SSP3-7.0)	16%	32%	64%	145%
Urban	Low Scenario (SSP1-2.6)	1%	1%	2%	2%
	High Scenario (SSP3-7.0)	1%	2%	4%	9%

The results, shown in the tables above, indicate that rural populations are much more likely to be impacted by HRI than urban populations. Other studies have demonstrated that living alone, underlying medical conditions, and lack of air conditioning are all risk factors for mortality during high heat days.[47] We only considered these factors in aggregate and did not separately analyze their contributions to changes in personal costs over an individual's lifetime. Moreover, the higher proportion of the population working outdoors is likely higher in rural areas than in urban areas, contributing to the higher rates of HRI with higher temperatures.[48]

The average length of an HRI hospital stay is 3.2 days and the average cost per day of hospitalization is $2,990, resulting in an average cost of $9,580 in 2024 US dollars. As the number of high heat days in the United States increases, there is an increased likelihood that more Americans will be afflicted with these costs due to higher rates of HRI.[49]

Respiratory Illness

The below tables describe the increase in the number of children diagnosed with respiratory illness from the baseline (Table 38) and the percentage increase in childhood cases of respiratory illness (Table 39Table 39) associated with PM2.5 and O_3.

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[46] US EPA (2016). "Climate Change Indicators: Heat-Related Illnesses," retrieved from: Climate Change Indicators: Heat-Related Illnesses | US EPA

[47] Jagai, Jyotsna et al (2017). "Hospitalization for heat-stress illness varies between rural and urban areas: an analysis of Illinois data, 1987-2014." Environmental Health, page 6, retrieved from: Hospitalizations for heat-stress illness varies between rural and urban areas: an analysis of Illinois data, 1987–2014 | Environmental Health | Full Text (biomedcentral.com); Semenza, Jan et al (1996), "Heat-related deaths during the July 1995 heat wave in Chicago." New England Journal of Medicine, page 84, retrieved from: Heat-related deaths during the July 1995 heat wave in Chicago - PubMed (nih.gov)

[48] Ibid.

[49] Merrill, CT et al (2011). "Hospital Stays Resulting from Excessive Heat and Cold Exposure Due to Weather Conditions in U.S. Community Hospitals, 2005." page 3, retrieved from: Hospital Stays Resulting from Excessive Heat and Cold Exposure Due to Weather Conditions in U.S. Community Hospitals, 2005 - Abstract - Europe PMC; The original cost per stay was reported in 2005 dollars. The ICF team inflated the value to 2024 US dollars.

Table 38. Increase in Number of Respiratory Illness Cases from Baseline.

Reported years	2034	2044	2064	2104
Low Scenario (SSP1-2.6)	10,870	18,790	25,030	22,320
High Scenario (SSP3-7.0)	13,730	27,470	55,150	125,440

Note: Baseline number of cases is 840,000.[50]

Table 39. Percentage Increase in Respiratory Illness Cases from Baseline.

Reported years	2034	2044	2064	2104
Low Scenario (SSP1-2.6)	1.3%	2.2%	3.0%	2.7%
High Scenario (SSP3-7.0)	1.6%	3.3%	6.6%	14.9%

A report by EPA on the impact of climate change on children's health in the U.S. has estimated that the cost of respiratory illness over the course of a lifetime, including lifetime medical expenses and the costs of lost productivity is $49,600. As seen in the tables above, there is likely to be an increase in the number of respiratory illness cases associated with climate change, indicating that more individuals in the U.S. will be burdened with this cost.[51]

Summary

Although it is difficult to estimate the increased cost of healthcare to an individual over the course of a lifetime, we have provided estimates on the projected increase in incidence rates for two of the several health conditions closely associated with a changing climate. As global temperatures continue to rise, the impacts on health and costs of medical care are likely to increase over the course of a lifetime.

Key takeaways:

- Heat-related illness is estimated to increase 145% (rural population) and 9% (urban population) by 2104, respectively under the high climate scenario. The average cost of HRI is $9,580 per case.
- Respiratory illnesses are estimated to increase 2.7% and 14.9% by 2104 under a moderate and extreme climate scenario, respectively. Lifetime costs associated with respiratory illness are $49,600, including medical expenses and the cost of lost productivity.
- The sum of the increases in healthcare costs due to climate change is likely much greater than shown here through the two illustrative impacts (i.e., HRI and respiratory illness).

Methodology for Entertainment Impacts

For this analysis, the financial impacts of climate change on entertainment were approached qualitatively. Historically, extreme weather, such as tropical cyclones, hurricanes, and extreme

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[50] United States Environmental Protection Agency [EPA] (2023). "Climate Change and Children's Health and Well-Being in the United States", Page 41, retrieved from: [Climate Change and Children's Health and Well-Being in the United States (epa.gov)]

[51] US EPA (2023). "Climate Change and Children's Health and Well-Being in the United States", Page 40, retrieved from: [Climate Change and Children's Health and Well-Being in the United States (epa.gov)]; reported in 2024 US dollars

precipitation, have disrupted flight schedules and patterns. The projected increase of these events is likely to further impact flights, creating an increased cost for consumers. In addition, the demand for companies to reduce carbon emissions may create an increased cost to consumers as passthrough from carbon reduction efforts. Further, rising sea levels could pose a risk to internet infrastructure, resulting in internet connectivity issues in the future. The following sections qualitatively describe how climate change is likely to impact the costs associated with travel and entertainment.

Results and Qualitative Discussion

Travel

The study "Total Deal Impact Study: A Comprehensive Assessment of the Costs and Impacts of Flight Delay in the United States," states that the total cost of flight delays to passengers is $6,975 million in 2024 US dollars.[52] The Federal Aviation Administration estimates that 0.9% of all delayed flights are delayed due to extreme weather.[53] This equates to approximately 149,470 flights delayed by weather annually. Because we do not know which extreme weather events most impact flight delays, we are using extreme precipitation (>=50mm in one day) and extreme heat (days above >48°C) for our estimates.[54] Extreme precipitation and extreme heat will increase under both climate scenarios indicating that flight delays will increase, which will lead to an increase in the cost of overall travel for an individual born in 2024.

Seasonal recreational activities, such as skiing, are likely to be most impacted by climate change. Although there is little evidence on the monetary impact of climate change on these activities, studies have described the estimated decrease in number of ski operating days due to warmer temperatures in the winter. One study from Steiger et al found that, under an extreme climate scenario (+4.4°C), there are likely to be 10.9 less ski operating days in the Northeast United States for the years 2040-2069.[55] This does not necessarily mean that skiing will cost more, but will result in spatial, activity, or temporal substitution.[56] These impacts suggest that the risk of climate change will fall more on investors and owners of some recreational activities. One study modeled the monetary impacts that climate change will likely have on the number of downhill skiing trips in the U.S. The study estimates that, under a lower warming scenario (SSP2-4.5), downhill skiing trips will be reduced by 20.6 million and, under a high warming scenario (SSP5-8.5), trips will be reduced by 36.6 million.[57]

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[52] The National Center of Excellence for Aviation Operations Research (2010), "Total Delay Impact Study: A Comprehensive Assessment of the Costs and Impacts of Flight Delay in the United States." Page 35, retrieved from: Total delay impact study : a comprehensive assessment of the costs and impacts of flight delay in the United States (bts.gov)

[53] Bureau of Transportation Statistics (2023), "Airline On-Time Statistics and Delay Causes: Flight Delays by Cause." Retrieved from: OST_R | BTS | Title from h2

[54] The ICF team was only able to project number of days over 38°C for the study time, therefore, we assumed that 10% of those days would be greater than or equal to 48°C.

[55] Steiger et al (2017), "A critical review of climate change risk for ski tourism." Current Issues in Tourism, page 1361, retrieved from: A critical review of climate change risk for ski tourism (tandfonline.com)

[56] Steiger et al (2017), "A critical review of climate change risk for ski tourism." Current Issues in Tourism, page 1358, retrieved from: A critical review of climate change risk for ski tourism (tandfonline.com)

[57] Wobus et al (2017), "Projected climate change impacts on skiing and snowmobiling: A case study of the United States." Global Environmental Change, page 10, retrieved from: Projected climate change impacts on skiing and snowmobiling_ A case study of the United States (sciencedirectassets.com)

Summary

Here, we qualitatively discuss the potential impacts of climate on the cost of entertainment-related consumer goods and internet infrastructure and connectivity. A report by the World Economic Forum discussed the potential impacts to consumers of companies' efforts to decarbonize their supply chains. The report estimated that the price of a $427 personal electronic device would increase by about 1%.[58]

A study on the impact of sea level rise on internet infrastructure finds that there is a risk to internet infrastructure and connectivity from rising sea levels. The paper states that approximately 41,000 miles of fiber conduit will be underwater by 2033.[59] Although we did not model the increased cost of travel and entertainment to an individual born in 2024, it is clear that climate change will have substantial impacts on these areas and is likely to increase their cost.

Key takeaways:

- Travel times will likely increase due to extreme weather.
- The current aggregate cost of flight delays to passengers is $6,975 million USD, and the current average time of flight delays due to weather is 70 minutes.
- Individuals will have to adjust their plans surrounding seasonal recreational activities, like skiing and fishing.
- Internet infrastructure and connectivity may be at risk due to rising sea levels.

Methodology for Utility Impacts

Electricity

Data and Assumptions

Our analysis of electricity system impacts relies on data from Jaglom et al. [60] The report provided data for two scenarios, a reference scenario (REF), where temperatures are based on unmitigated projected emissions and a RF3.7, which represent a future assuming limitations on global GHG emissions such that the radiative forcing (RF) level in 2100 is stabilized at 3.7 W/m2. For both scenarios, the report estimated national CDD, HDD, cooling demand, and heating demand.[61] On the regional level, the report projected percent change for the same categories.[62]

To convert the paper's results to the low scenario (SSP1-2.6) and the high scenario (SSP3-7.0), we determined a conversion rate based on cooling and heating degree days (CDD and HDD).

(1) $Multiplier_{CDD,low} = CDD_{SSP1-\ \ .6,2050}/CDD_{RF3.7,2050}$

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[58] World Economic Forum (2021), "Net-Zero Challenge: The supply chain opportunity." Page 6, retrieved from: WEF_Net_Zero_Challenge_The_Supply_Chain_Opportunity_2021.pdf (weforum.org)

[59] Durairajan, Ramakrishnan et al (2018), "Lights Out: Climate Change Risk to Internet Infrastructure." Association for Computing Machinery, page 6, retrieved from: Lights Out: Climate Change Risk to Internet Infrastructure (uoregon.edu)

[60] Jaglom et al (2014). "Assessment of projected temperature impacts from climate change on the U.S. electric power sector using the Integrated Planning Models." Energy Policy, page 528, retrieved from: https://doi.org/10.1016/j.enpol.2014.04.032

[61] Ibid, page 530

[62] Ibid, page 529-530

The conversion rate was repeated to calculate multipliers across scenarios and HDD. ICF then divided annual CDD and HDD projections by the multiplier determined in (1) to get annual CDD and HDD for the RF3.7 and REF scenarios. Using the annualized CDD and HDD and under the assumption that the relationship between CDD / HDD and cooling/heating demand is linear, we calculated the relationship between CDD/HDD and cooling/heating demand based on Jaglom et al's .

(2) $Demand_{GWh,RF3.7,Cooling} = (Cooling\ Demand_{RF3.7,2050} - Cooling\ Demand_{RF3.7,2012})/CDD_{RF3.7,2050}$

The results of equation (2) were calculated for both RF3.7 and REF scenarios and CDD/HDD, shown in Table 40. For example, as CDD increases by 1 day per year, consumption of electricity increases by 2190 GWh. To transpose the paper's cooling and heating demand projections, we assumed a constant relationship between CDD/HDD and cooling/heating demand. As such, ICF applied the demand multipliers in Table 40 to the CDD and HDD projections under SSP1-2.6 and SSP3-7.0, shown in (3).

(3) $Electricity\ Demand_{cooling,SSP1-\ .6,year} = Demand_{GWh,RF3.7,Cooling} * CDD_{SSP1-2.6,year}$

Table 40. Demand Multipliers.

GWh Demand, CDD to Cooling		GWh Demand, HDD to Heating	
RF3.7	**REF**	**RF3.7**	**REF**
2190	1203	13	13

ICF then calculated the percentage change in national electricity demand from both heating and cooling from the base year, 2024, shown in Table 41.

Table 41. Change in Cooling and Heating Demand, Percentage.

	Cooling		Heating	
Year	**SSP1-2.6**	**SSP3-7.0**	**SSP1-2.6**	**SSP3-7.0**
2024	0%	0%	0%	0%
2034	19%	20%	-1%	-2%
2044	35%	42%	-3%	-4%
2064	54%	93%	-4%	-9%
2104	46%	218%	-3%	-18%

National to location-specific extrapolation

Jaglom et al. presented location-specific changes in CDD, HDD, cooling demand, and heating demand as ranges of percent changes. In our calculations, we used the ranges' midpoints. ICF assumed that the relationship between CDD/HDD and cooling/heating demand is the same everywhere as it is nationally. The relationship was calculated using (4) for heating and cooling under both scenarios.

(4) $Demand\ Multiplier_{Cooling,Location,RF3.7} = \Delta Demand_{RF\ .7,Location,Cooling}/\Delta Demand_{RF\ .7,National,Cooling}$

Next, to fit location-specific results to SSP1-2.6 and SSP3-7.0 scenarios, ICF applied results of (4) to the national estimates. This created persona-specific results for 2024, 2034, 2044, 2064, and 2104, shown in Table 42.

Table 42. Changes in Electricity Demand by Persona.

	Persona A, Tampa FL				Persona B, Reno NV			
	Cooling		Heating		Cooling		Heating	
Year	**SSP1-2.6**	**SSP3-7.0**	**SSP1-2.6**	**SSP3-7.0**	**SSP1-2.6**	**SSP3-7.0**	**SSP1-2.6**	**SSP3-7.0**
2024	0%	0%	0%	0%	0%	0%	0%	0%
2034	3%	5%	-1%	0%	3%	5%	-3%	-5%
2044	5%	10%	-1%	-1%	5%	10%	-6%	-11%
2064	8%	22%	-2%	-2%	8%	22%	-8%	-23%
2104	7%	52%	-1%	-4%	7%	52%	-6%	-48%

	Persona C, Vinton IA				Persona D, Boston MA			
	Cooling		Heating		Cooling		Heating	
Year	**SSP1-2.6**	**SSP3-7.0**	**SSP1-2.6**	**SSP3-7.0**	**SSP1-2.6**	**SSP3-7.0**	**SSP1-2.6**	**SSP3-7.0**
2024	0%	0%	0%	0%	0%	0%	0%	0%
2034	5%	9%	-2%	-3%	5%	9%	-3%	-3%
2044	8%	19%	-3%	-7%	8%	19%	-6%	-7%
2064	13%	41%	-5%	-14%	13%	41%	-8%	-14%
2104	11%	97%	-4%	-30%	11%	97%	-6%	-30%

ICF then weighted heating and cooling demand using EIA average cooling and heating consumption for each state.[63] For the locations of interest, we calculated the weight following the equations in (5) and (6).

(5) $Multiplier_{state,cooling} = Consumption,_{state,cooling}/\big(Consumption,_{state,cooling} + Consumption,_{state,heating}\big)$

(6) $Multiplier_{state,heating} = Consumption,_{state,heating}/\big(Consumption,_{state,cooling} + Consumption,_{state,heati}\big)$

Finally, to incorporate changes in price in addition to changes in demand, ICF utilized electricity demand projections calculated by the climate team. This represents the actual increased cost in the basket of goods to the consumer. These results were calculated following (7). Table 43 presents the findings of percent change in electricity cost by persona.

(7) $cost\ to\ household_{year} = cost\ to\ household_{2024} * \big(1 + \Delta\ electricity\ demand_{year}\big) * (1 + \Delta\ electricity\ price_{year})$

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[63] U.S. EIA (2020). "Residential Energy Consumption Survey (RECS) Dashboard", retrieved from: https://experience.arcgis.com/experience/cbf6875974554a74823232f84f563253

Table 43. Change in Household Electricity Cost, multiplier.

	Persona A, Tampa FL		Persona B, Reno NV		Persona C, Vinton IA		Persona D, Boston MA	
Year	**SSP1-2.6**	**SSP3-7.0**	**SSP1-2.6**	**SSP3-7.0**	**SSP1-2.6**	**SSP3-7.0**	**SSP1-2.6**	**SSP3-7.0**
2024	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2034	1.14	1.03	1.14	1.02	1.09	0.95	1.16	1.07
2044	1.27	1.04	1.26	1.03	1.17	0.88	1.32	1.13
2064	1.40	1.11	1.39	1.08	1.24	0.78	1.48	1.30
2104	1.32	1.22	1.31	1.18	1.19	0.54	1.38	1.66

Water

Water use grows almost linearly with the increase in population.[64] As such, ICF assumed that water demand per household remains constant. Additionally, as water price is most commonly priced at a uniform rate in the United States, ICF assumes that price remains constant.[65] Although areas of the United States will experience low water supply, such as areas currently supplied by the Colorado River, Henderson et al. (2015) finds that in periods of reduced availability, water will be reallocated to supply uses with higher marginal values, including household water consumption.[66] Instead of a direct household impact, the impacts will fall on sectors such as hydroelectric power generation and agriculture. In drier regions, such as areas that rely on the Colorado River, water may be moved away from uses that have lower marginal values, or areas may improve technology and efficiency or implement adaption actions, such as the increased use of recycled water. As such, ICF does not project a general increase in the cost of water passed on to households, with some regional exceptions.

To translate the projected changes in electricity and water consumption, ICF used EPA's estimate that the average U.S. household spends $1,000[67] annually on their water bill and $1884[68] on their average energy expenditure. As such, ICF assumed that 65% of utility prices were variable and 35% remain constant at 2024 levels.

Gasoline Consumption Estimates

While the per gallon prices of gasoline were estimated using the Global Change Assessment Model (GCAM), the overall consumption by household was estimated to determine the impact on household budgets. Therefore, ICF utilized annual transportation motor gas energy use projections through 2050 from U.S. EIA's Annual Energy Outlook (AEO) to estimate overall energy use for transportation by

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[64] Hejazi, Mohamad et al (2013). "Scenarios of global municipal water-use demand projections over the 21st century." Hydrological Sciences Journal, 58:3, page 521, retrieved from: https://doi.org/10.1080/02626667.2013.772301

[65] U.S. EPA (2023), "Understanding Your Water Bill." retrieved from: https://www.epa.gov/watersense/understanding-your-water-bill.

[66] Henderson, J et al. (2015). "Economic impacts of climate change on water resources in the coterminous United States. Mitigation and Adaptation Strategies for Global Change." 20(1), 135-157. https://doi.org/10.1007/s11027-013-9483-x.

[67] U.S. EPA (2023). "WaterSense, Statistics and Facts." retrieved from: https://www.epa.gov/watersense/statistics-and-facts.

[68] U.S. EIA (2023). "Table CE3.6 Annual household site end-use expenditures in the United States—totals and averages, 2020." retrieved from: https://www.eia.gov/consumption/residential/data/2020/index.php?view=consumption#by%20end%20uses.

household.[69] Transportation motor gas energy consumption projections decrease annually until 2044, and then remain relatively constant through 2050. As such, ICF assumed that transportation motor gas demand remains constant from 2050 through 2104, at 17% less than 2024. ICF also assumed that household transportation gasoline demand for household decreases at the same rate as the entire transportation gasoline sector. ICF then applied the change in gasoline demand for the transportation sector to the change in gasoline prices projected by the GCAM (see Table 2, GCAM) analysis for low and high climate scenarios following the equation in (8), using 2044 as an example.

Although gasoline consumption is anticipated to decrease overtime, other shifts will also influence household preferences that will also affect travel patterns or vehicle choice. Technologies, such as electric vehicles (EVs) and policies that incentivize a shift away from fossil fuels have the potential to reduce household gasoline demand. In addition, recent literature has found the price elasticity of gasoline demand to be larger than previously estimated, with the price elasticity in 2009 and 2017 increasing from -0.050 to -0.291, respectively.[70] Put into context, a "10% increase in the fuel price would result in a roughly 2.9% decrease in VMT."[71] Additional literature finds the price elasticity even higher, with price elasticity of gasoline demand at -0.37.[72] Higher price elasticities of demand signify that as fuel prices increase, or as fuel prices become more volatile due to shocks, including those from climate change, household will consume less or substitute gasoline vehicles with EVs.

The results of this analysis found that gasoline consumption will be lower under the low scenario as it is expected fuel prices and alternative fuel technology will influence some households to change travel patterns and vehicle purchases. Whereas under the high scenario cheaper gasoline will be available initially influencing more gasoline based travel resulting in higher GHG emissions, and a transition to higher fuel costs after 2064. In the long-run fuel prices for transportation will be worse under the high scenario.

$$(8)\quad Houshold\ Gasoline\ Spending_{2044} = Household\ Gasoline\ Spending_{2024}(1 + \%\Delta Gasoline\ Demand_{2044})(1 + \%\Delta Gasoline\ Price_{2044})$$

Summary

The key takeaways from this analysis include:

- Nationally, households are estimated to spend 176% and 257% more under low and high climate scenarios by 2104, respectively.
- Under the high scenario (SSP3-7.0) households in areas of the Midwest and Northeast, such as Vinton IA and Boston, MA, are estimated to pay 72% less electricity costs in 2104 from 2024 driven by decreases in heating use outpacing increases in cooling use, while households in the other areas of the country, such as Tampa, FL are expected to pay 122% more in electricity costs.

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[69] U.S. EIA (2023). "Table 2. Energy Consumption by Sector and Source." retrieved from: https://www.eia.gov/outlooks/aeo/data/browser/#/?id=2-AEO2023&region=1-0&cases=ref2023&start=2021&end=2050&f=A&linechart=ref2023-d020623a.3-2-AEO2023.1-0~ref2023-d020623a.57-2-AEO2023.1-0~ref2023-d020623a.56-2-AEO2023.1-0&map=ref2023-d020623a.3-2-AEO2023.1-0&ctype=linechart&sourcekey=0

[70] Goetzke, Frank et al. "An increasing gasoline price elasticity in the United States?" Energy Economics, 95, page 8

[71] Ibid pg 5

[72] Federal Reserve Bank of Dallas (2020), "Gasoline demand more responsive to price changes than economists once thought." Retrieved from: https://www.dallasfed.org/research/economics/2020/0616.

- Water prices are forecasted to remain constant, as it is unclear how states will adjust prices for households and other activities including industrial and farming. Supply shortages are likely in the southwestern states and may result in tiered pricing or other policies to limit consumption by use types to limit water consumption. The water estimate therefore for the southwestern states is likely an underestimate of future water costs.
- Gasoline is expected to cost households 498% and 83% more under the low and high emissions scenarios respectively, largely due to increased prices in fossil fuels under the low emissions scenario.

Climate Impacts to Net Income

To estimate the impacts of climate change on net income, our analysis quantifies the projected impacts of climate change on employment income, retirement income, and personal taxes under SSP1-2.6 and SSP3-7.0.

The following net income methodology section will first discuss how we derived estimates for the person's baseline net income. We discuss how we calculated an annual time series from 2024-2104 for baseline GDP, baseline population, and baseline employed population. We then describe how we use the baseline GDP, baseline population, and baseline employed population estimates, in conjunction with other credible data sources, to estimate the baseline employment income for the person throughout their working lifetime (age 20-61). This baseline employment income, along with the baseline employed population, then feeds into how we derived the person's baseline retirement income which is discussed next. Lastly, for our net income baseline methodology, we describe how we estimated the person's baseline personal taxes and our total baseline net income.

After establishing how we calculated our baseline estimates, we then moved on to describe the detailed process of how we estimated the impacts of climate change on employment income, retirement income, and personal taxes. We discussed impacts on employment income first, because our estimates for employment income loss feed into our retirement income model in the next section. Specifically, the more the person loses in their annual employment income from climate change, the less they have to invest each year into their retirement savings. We then describe the impacts of climate change on personal taxes. At the end of the net income methodology, in the macroeconomic burden methodology section, we also discuss how we calculated estimates for GDP percent loss due to climate change under each scenario. These GDP loss estimates are not a central focus of the main report as GDP loss numbers are not very tangible for the individual consumer, but we used these estimates as part of our methodology for estimating the impacts of climate change on personal tax increases for the average consumer. After describing our full methodology, we then provide a summary our quantified estimates for the climate impacts of net income under the low climate scenario (SSP1-2.6) which are not included in the main report.

Due to limited data, our analysis did not estimate the quantitative effects of all projected climate change impacts on net income. **The net income numbers presented in the report are thus an underestimate of the total financial impact of climate change on net income.** Furthermore, the analysis team had to make several assumptions to address gaps in available data. These assumptions lead to uncertainty in the estimates. The analysis team captured some of the uncertainty associated with future GHG emissions by considering both high and low climate change scenarios. Nonetheless, as the first summary of consumer-level impacts of climate change, the analysis team believes the information in this report provides useful estimates.

Baseline Net Income Calculations

Baseline GDP

ICF obtained data about the forecasted US Gross Domestic Product (GDP) from the OECD[73]. The dataset projects the US GDP up to 2060 in 2010 dollars. ICF performed a linear regression in Excel using the LINEST function to further project the US GDP out to 2104, using the following formula: Y = 396,893x + 20,296,980. Subsequently, ICF converted US 2010 dollars to 2024 dollars.

Baseline Population

ICF obtained baseline population[74] data from the OECD and utilized a 1st degree polynomial in Excel using the LINEST function. The coefficients are described in the below equation:

(9) $Y = 1{,}481{,}980X + 333{,}622{,}220$

Baseline Employed Population

We calculated a constant ratio (0.467) of the total U.S. population to the employed population by dividing the average annual employed population from the BLS[75] data for 2018-2022 (154,398,567) by the average annual total U.S. population from BEA[76] (331,408,200). We multiplied the annual time series of the baseline total U.S. population from 2024-2104 by the ratio of total population to employed population to obtain an annual time series of the U.S. employed population without climate impacts.

Baseline Employment Income Per Worker (not age adjusted)

To estimate the baseline employment income of the person born in 2024 without climate impacts over their lifetime, we used the employment income data (i.e., “Wages and Salaries”) from the Bureau of Economic analysis (BEA) from 2018-2022.[77]

For each year from 2018-2022, we converted the total employment income data for that year into 2024 dollars and divided by the corresponding year’s employment level from the Federal Reserve Bank of St. Louis (FRED)[78] to estimate the average annual employment income per worker. We then used the average for the years 2018-2022 to estimate an average annual employment income per worker for the 2018-2022 period. See Table 44 for these calculations.

Table 44. Average Annual Employment Income per Worker.

Year	Annual employment income per worker ($2024)

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[73] OECD (2023). “Real GDP long-term forecast (indicator)”. GDP and spending - Real GDP long-term forecast - OECD Data

[74] OECD (2023). “Population (indicator)”. Demography - Population - OECD Data

[75] U.S. Bureau of Labor Statistics. (2023), Employment Level [CE16OV], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/CE16OV

[76] BEA. (2023) “Previously Published Estimates,” Section 2, Table 2.1 Personal Income and Its Disposition, retrieved from: https://apps.bea.gov/.

[77] BEA (2023). “Previously Published Estimates,” Section 2, Table 2.1 Personal Income and Its Disposition, retrieved from: https://apps.bea.gov/.

[78] U.S. Bureau of Labor Statistics (2023). “Employment Level [CE16OV]”, retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/CE16OV

2018	$69,980
2019	$71,301
2020	$76,105
2021	$76,879
2022	$74,666
Average 2018-2022	**$73,786**

Next, we used the average annual U.S. real GDP from the BEA[79] from 2018-2022 ($26.147 billion) and divided that by the average annual U.S. employment level from FRED[80] from 2018-2022 (154,398,567) to estimate the average annual GDP per worker ($169,344). We then divided the average employment income from 2018-2022 in Table 44 by the average annual GDP per worker to obtain a ratio of the average annual wage per worker to average GDP per worker from 2018-2022 (0.436). This ratio was then multiplied by the annual GDP per worker estimates for every year from 2024-2104 to estimate the annual employment income per worker from 2024-2104 without climate impacts.

The aforementioned time series of annual GDP per worker from 2024-2104 was estimated from the annual time series of GDP and employed population without climate impacts. Both of these time series were created using a linear polynomial smoothed fitting from OECD GDP and population data without climate change (see section on Polynomial Fitting & Extrapolation).[81] We used the annual time series of U.S. GDP without climate impacts and divided by the annual time series of the U.S. employed population to obtain the annual time series of GDP per worker.

Baseline employment income over the person's lifetime (age adjusted)

After deriving the average annual employment income per worker from 2024-2104, we created an age-adjusted time series for the person born in 2024. To do this, we made an assumption that the person would not earn employment income until age 20 and that they would retire at age 61.[82] Therefore, they would not have any employment income before 2044 and after 2085.

To create the age-adjusted employment income time series, we used the average annual U.S. salary and wage data by age for ages 20-61 from IPUMS Current Population Survey (CPS) created jointly by the U.S. Census Bureau and the BLS.[83] Generally, when a person is young, they earn less than when they are older. We smoothed the data from IPUM CPS using a 4th degree polynomial, since the data set has a few outlier averages that disrupt the general trend of increasing employment income with age.

Next, we created a ratio for every year of the average employment income by age divided by the average of all average employment income by age from ages 20-61. We then multiplied that ratio by the

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[79] U.S. Bureau of Economic Analysis (2023). Real Gross Domestic Product [GDPC1], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/GDPC1

[80] U.S. Bureau of Labor Statistics (2023). Employment Level [CE16OV], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/CE16OV

[81] OECD (2023). "Population (indicator)". Demography - Population - OECD Data

[82] Jones, Jeffrey (2022). "More in U.S. Retiring, or Planning to Retire, Later." Gallup, https://news.gallup.com/poll/394943/retiring-planning-retire-later.aspx.

[83] Flood, Sarah; King, Miriam; Rodgers, Renae; Ruggles, Steven; Warren, Robert; Backman, Daniel; Chen, Annie; Cooper, Grace; Richards, Stephanie; Schouweiler, Megan; Westberry, Michael (2023). IPUMS CPS: Version 11.0 [dataset]. Minneapolis, MN: IPUMS, 2023. https://doi.org/10.18128/D030.V11.0

baseline annual wage per worker (not age adjusted) described above. This calculation is illustrated in Table 45 with the years 2044-2047 as an example.

Table 45. Baseline Employment Income for Ages 20-61 Calculations.

A	B	C	D	E	F	G
Year	**Baseline Annual Wage per worker**	**Age**	**Raw income by age group from IPUM CPS**	**Smoothed data from IPUM CPS**	**Average of all IPUM CPS data from 2044-2085**	**Age-adjusted baseline employment income = (Column E/Column F) * Column B**
2044	$105,612.42	20	$25,987.02	$22,558	$72,253.40	$32,972.76
2045	$106,590.10	21	$28,136.10	$28,484	$72,253.40	$42,020.57
2046	$107,560.00	22	$30,790.80	$34,007	$72,253.40	$50,625.14
2047	$108,522.20	23	$36,196.32	$39,147	$72,253.40	$58,797.02

Baseline retirement savings methodology

To calculate the baseline retirement savings under a no climate change scenario, we used the age-adjusted baseline employment income from ages 20-61 (2044-2085). We assumed the person would not invest any of their employment income until their annual wage exceeded $40,000, which is age 21 for the baseline and both climate scenarios. The baseline retirement income model assumes a 7.0% annual rate of return for investments for every year from 2044-2104, based on the historical average annual rate of return for a risk averse portfolio comprised of 20% stocks and 80% bonds, according to Vanguard[84]. We assumed that a person chooses to invest a constant percent of their employment income within certain age brackets to meet retirement savings goals. Specifically, we assumed that under the baseline scenario, the person will save 1x their salary by the age of 30, 3x by 40, 6x by 50, 8x by 60, and 10x by 67.[85] We adjusted the percent of employment income invested within each of these age brackets to be constant, and so that their total savings will exactly hit their goal savings by the goal year. For example, for the baseline scenario, by age 30 the person has a goal of savings equal to 1x their salary at age 30, which is $104,834. We adjusted the percent of employment income that is invested to be a constant of 9.862% from age 21 to 30 so that their total savings at age 30 are exactly equal to their goal savings of $$104,834. Similarly, for the baseline scenario, by age 40 the person has a goal of savings equal to 3x their salary at age 40. Their salary at age 40 is $142,595, so their savings goal is $427,785 ($104,834*3). We adjusted the percent of employment income that is invested to be a constant of 11.901% from age 31 to 40 so that their total savings at age 40 are exactly equal to their goal savings of $427,785.

During the person's working lifetime, the model calculates the person's total cumulative savings at the end of each year by first taking the employment income of the person for that year multiplied by the percent of employment income the person invests to obtain the amount of employment income invested. Next, total savings are calculated as the total savings of the previous year plus the amount of

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[84] Vanguard (2023). "Vanguard Portfolio Allocation Models," retrieved from: https://investor.vanguard.com/investor-resources-education/education/model-portfolio-allocation.

[85] Fidelity (2023). "How Much Do I Need to Retire? Fidelity", retrieved from: https://www.fidelity.com/viewpoints/retirement/how-much-do-i-need-to-retire.

employment income invested, times the annual rate of return of 7.0%. Annual returns are calculated as the difference between the current year and the previous year's total cumulative savings.

After retirement, for ages 62-80, we assumed zero employment income but $22,685 in average annual social security income.[86] The model assumes that at age 62, the person starts off with the total cumulative savings they had at the end of age 61. We assumed retirees would withdraw and spend 80% of their pre-retirement income at age 61, for each year of retirement. So, their net withdrawal from their savings every year would be 80% of their pre-retirement income ($118,365) minus $22,685. Their annual returns during their retirement years are calculated using the formula below.

$$\textit{Annual investment returns during retirement}_{\textit{in year X}} = (\textit{Total Savings}_{\textit{in year X-1}} + (\textit{Total Savings}_{\textit{in year X-1}} - \$118{,}365 + \$22{,}685)/2)*7.0\%\ \textit{Annual rate of return}$$

Their total savings at the end of each year in retirement are then calculated using the formula below:

$$\textit{Total savings during retirement}_{\textit{in year X}} = (\textit{Total Savings}_{\textit{in year X-1}} - \$118{,}365 + \$22{,}685) + \textit{Annual investment returns}_{\textit{in year X}}$$

In the baseline scenario, the person gains $2,592,578 in lifetime investment returns (calculated as the sum of annual returns on investments from age 21 to 80) and has $774,673 left in total savings at the age of 80. Their lifetime gains in investment returns are greater than their total savings left at age 80, because although the person still gains investment returns during their retirement years, they spend more than their annal investment returns during retirement and their overall savings pot shrinks.

Baseline taxes methodology

We assume that the person does not pay taxes until they earn a wage, which is at age 20 (year 2044). We then assume the person pays taxes for the rest of their lifetime from age 20-80. For the person's working lifetime (ages 20-61), baseline taxes were calculated using the age-adjusted annual baseline employment income and an assumption of the percentage of employment income that a person pays in taxes. To calculate this assumption, ICF used "Wages and Salaries" data from the BEA from 2018-2022. [87] We then used the average of these values to get the average U.S. total employment income from 2018-2022 shown in Table 46.

Table 46. Average U.S. Total Employment Income from 2018-2022.

Year	Annual U.S. Wages and Salaries (millions $2024)
2018	10,900,327.55
2019	11,232,373.62
2020	11,249,316.58
2021	11,730,621.94
2022	11,819,379.46
Average 2018-2022	11,386,403.83

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[86] SSA (2023). "Monthly Statistical Snapshot, November 2023." Social Security Administration, Table 2, retrieved from: https://www.ssa.gov/policy/docs/quickfacts/stat_snapshot/.

[87] BEA (2023). "Previously Published Estimates," Section 2, Table 2.1 Personal Income and Its Disposition, retrieved from: https://apps.bea.gov/.

Next, for each year from 2018-2022 ICF gathered data on the total amount of personal taxes paid in the United States. We assume that the government will increase individual income taxes, sales taxes, and corporate taxes to make up for the climate losses in government tax revenue and increases in governmental expenses due to climate damages. In other words, we assume the government will not increase social insurance to make up for climate change-induced losses in government revenue. Because of this, for our analysis we assume that the baseline total personal taxes only include individual income taxes and sales/excise taxes. Our estimates of the impacts of climate change on personal taxes relative to the baseline are adjusted to exclude the estimated impacts on corporate income taxes. This is explained in further detail in the taxes methodology section below.

ICF used data from OMB on annual total government revenues from 2018-2022.[88] ICF calculated the baseline personal tax for these years by adding the total amount of individual income taxes and sales/excise taxes collected by the government per year and converting every year to 2024 dollars. We then used the average of these values to obtain the average total personal taxes paid in the United States from 2018-2022, as shown in Table 47.

Table 47. Average Total Personal Taxes Paid in the U.S.

Year	Annual U.S. Personal Taxes (millions $2024)
2018	2,178,300.85
2019	2,188,390.15
2020	2,015,139.19
2021	2,411,104.57
2022	2,891,970.57
Average 2018-2022	**2,336,981.07**

We then calculated the percent of total personal taxes relative to total employment income by dividing the average values found in the tables above (20.5% = 100 * 2,336,981/11,386,403.83). We then multiplied this percentage by the person's baseline age-adjusted wage from age 20-61 to estimate their annual baseline personal taxes for their working lifetime.

For ages 62-80, the person no longer has a wage to which this tax rate (20.5%) is applicable. So, for these years, we assumed a ratio of the average percentage of retirement income (inclusive of social security income) that a retiree pays in total taxes, based on a study by The Center for Retirement Research at Boston College, which concluded that the average single retiree pays 7.2% of their retirement income in taxes.[89] It is important to note that the study assumes social security benefits as part of taxable retirement income, along with income from Employer-Sponsored Retirement Plans, taxation of other financial assets, and state taxes. This 7.2% value also assumes that retirees follow the

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[88] OMB (2024). "Historical Tables." The White House, Table 2.1 – Receipts by Source:1934-2028, retrieved from https://www.whitehouse.gov/omb/budget/historical-tables/.

[89] Chen, Anqi, and Alicia Munnell (2020). "How Much Taxes Will Retirees Owe on Their Retirement Income?" *SSRN Electronic Journal*, Table 6. Retirement Taxes as a Percentage of Retirement Income, Households Follow RMD and Consume Only Interest and Dividends from Financial Assets, by AMIE Quintile and Marital Status, retrieved from: https://doi.org/10.2139/ssrn.3786216.

required minimum distributions for their IRAs and employer-sponsored retirement plans and they consume only interest and dividends from financial assets. We applied the 7.2% tax rate to the person's annual retirement investment returns to obtain their annual baseline taxes paid for their retired years. The calculation of retirement returns is explained in the retirement income section.

Total baseline net income methodology

To calculate the total baseline net income for every year from 2044-2104, we added the person's baseline age adjusted annual employment income plus their baseline annual retirement investment income earnings minus their annual baseline taxes paid). See the sections above for details on how we derived each of these individual estimates.

To be consistent with our previous calculations, we assumed that the person has $0 in net income before age 20, that they receive a wage from ages 20-61, that they do not invest and receive retirement investment earnings until their annual wage exceeds $40,000 (age 21), and that they pay taxes from ages 20-80.

Climate Scenario Impacts on Net Income:

Methodology for Impacts on Total U.S. and Regional Employment Income

Introduction

Climate change is expected to impact earnings for US households.[90] Climate change may affect household earnings through several channels. For instance, rising temperatures may impact labor supply and productivity for several industries. Higher temperatures can create physical and cognitive discomfort as well as fatigue.[91] As a result, higher temperatures can reduce the time people allocate to work, as well as their productivity at work, particularly in highly exposed industries.[92] Employees who work outdoors (e.g., in farming and construction), as well as in industries such as utilities and manufacturing, are more exposed to the impacts higher temperatures.[93] Moreover, high temperatures can create unsafe working conditions that may require business closures which may decrease

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[90] Martinich, Jeremy (2023). "Fifth National Climate Assessment" U.S. Global Change Research Program, Chapter 19: Economics, retrieved from: https://nca2023.globalchange.gov/chapter/19/

[91] Heal, Geoffrey, and Jisung Park (2016). "Reflections—Temperature Stress and the Direct Impact of Climate Change: A Review of an Emerging Literature." Review of Environmental Economics and Policy, page 352, retrieved from: https://doi.org/10.1093/reep/rew007; Graff Zivin, Joshua, and Matthew Neidell (2014). "Temperature and the Allocation of Time: Implications for Climate Change." Journal of Labor Economics, page 1, retrieved from https://doi.org/10.1086/671766.

[92] Heal, Geoffrey, and Jisung Park (2016). "Reflections—Temperature Stress and the Direct Impact of Climate Change: A Review of an Emerging Literature." Review of Environmental Economics and Policy, page 352, retrieved from: https://doi.org/10.1093/reep/rew007; Graff Zivin, Joshua, and Matthew Neidell (2014). "Temperature and the Allocation of Time: Implications for Climate Change." Journal of Labor Economics, page 2, retrieved from https://doi.org/10.1086/671766

[93] Graff Zivin, Joshua, and Matthew Neidell (2014). "Temperature and the Allocation of Time: Implications for Climate Change." Journal of Labor Economics, page 2, retrieved from: https://doi.org/10.1086/671766; as Dahl, Kristina and Licker, Rachel (2021). "Too Hot to Work Assessing the Threats Climate Change Poses to Outdoor Workers", Union of Concerned Scientists, page 2, retrieved from: https://www.ucsusa.org/resources/too-hot-to-work; Behrer, A. P et al (2021). "Heat Has Larger Impacts on Labor in Poorer Areas." Environmental Research Communications, page 11, retrieved from: https://doi.org/10.1088/2515-7620/abffa3.

employment and labor hours, reducing earnings.[94] When exposed to hazardously high temperatures, workers are at a higher risk of experiencing heat-related illness and fatigue and therefore may take more frequent breaks or cease work entirely, resulting in lower labor capacity.[95]

This section details the methodology used to estimate estimated the aggregate impacts of climate change on employment in the United States. This analysis aims to take data sources for lost employment income due to extreme temperature to interpolate quantified estimates of the annual impacts of climate change on American employment income from 2024-2104. It is important to understand that lost labor hours due to unsuitable working conditions due to extreme temperatures represents just one dimension of the possible climate related impacts to employment income.

Assumptions

Our analysis requires the assumption that there is a linear relationship between temperature and lost labor hours.

To begin the analysis, we conducted research into existing, credible sources for quantified data projections of the impact of climate change on employment income under different climate change scenarios. For employment income data, we used projected data for lost employment income caused by lost labor supply hours due to changes in hot and cold temperature, including extreme temperatures for the whole U.S. as well as individual U.S. regions from a 2017 analysis done by the Climate Change Impacts and Risk Analysis (CIRA) project coordinated by the EPA for the fourth National Climate Assessment.[96] The report provided projections under SSP2- 4.5 and SSP5- 8.5 for the years 2050 and 2090 (see Table 48).

Table 48. Lost Employment Income from the CIRA Report (Millions of $2015).

	2050		**2090**	
	4.5	**8.5**	**4.5**	**8.5**
Northeast	4100	4600	8300	19000
Southeast	11000	14000	23000	47000
Midwest	8200	9800	17000	33000
Northern Plains	550	690	1300	2600
Southern Plains	6900	8900	18000	28000
Southwest	3900	6100	12000	23000
Northwest	220	350	730	1900
U.S. Total	**35000**	**44000**	**80000**	**160000**

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[94] U.S. Department of the Treasury (2023). "The Impact of Climate Change on American Household Finances", page 5, retrieved from https://home.treasury.gov/system/files/136/Climate_Change_Household_Finances.pdf

[95] Graff Zivin, J. and M. Neidell, (2014). Temperature and the allocation of time: implications for climate change. Journal of Labor Economics, 32, 1-26, doi:10.1086/671766

[96] EPA. (2017). Multi-model framework for quantitative sectoral impacts analysis: A technical report for the Fourth National Climate Assessment. U.S. Environmental Protection Agency, EPA 430-R-17-001.

Scaling Across Time and Climate Scenarios for Wage Losses

For our analysis the selected 2050 and 2090 wage loss data from the 2017 EPA CIRA report must be interpolated for SSP3-7.0 and SSP1-2.6 for the years 2024, 2034, 2044, 2064, 2084. The following section describes the methodology for this interpolation.

First, we interpolated the climate change impact on employment income for each year the data was initially provided in for SSP3-7.0 and SSP1-2.6. The equation below shows an example of how we interpolated employment income data provided for SSP2-4.5 and SSP5-8.5 for SSP3-7.0:

$$(1)\quad \text{Wage Loss}_{7.0} = ((7.0 - 4.5) / (8.5 - 4.5))*(\text{Wage Loss}_{8.5} - \text{Wage Loss}_{4.5}) + \text{Wage Loss}_{4.5}$$

Table 49. Lost Employment Income SSP1-2.6 and SSP3-7.0, Interpolated Results (Millions of $2015).

Year	**2050**		**2090**	
	2.6	**7.0**	**2.6**	**7.0**
Northeast	3862.5	4412.5	3217.5	14987.5
Southeast	9575	12875	11600	38000
Midwest	7440	9200	9400	27000
Northern Plains	483.5	637.5	682.5	2112.5
Southern Plains	5950	8150	13250	24250
Southwest	2855	5275	6775	18875
Northwest	158.25	301.25	174.25	1461.25
U.S. Total	**30725**	**40625**	**42000**	**130000**

Next, we took our SSP3-7.0 and SSP1-2.6 wage loss interpolations and divided the result by the annualized average temperature for both the high and low emissions scenarios of the given year to get a cost-temperature ratio using equation (11).

$$(2)\quad \text{Wage Loss-Temperature Ratio}_{\text{in year } x} = \text{Wage Loss}_{\text{in year } x} / \text{Temperature}_{\text{in year } x}$$

Once Wage Loss-Temperature ratios are calculated for the SSP3-7.0 and SSP1-2.6 projections, we can calculate Income loss for 2024, 2034, 2044, 2064, 2084 and 2104. For this portion of the interpolation work, temperature change data will be used to extrapolate the projected wage losses for 2024, 2034, 2044, 2064, 2084 and 2104. For the years 2024, 2034, 2044 and 2104 values can be calculated using equation (12).

$$(3)\quad \text{Wage Loss}_{\text{interpolated year}} = \text{Wage Loss}_{2050} *(\text{Temperature}_{\text{interpolated year}} / \text{Temperature}_{2050})$$

When calculating for a year earlier than 2050 the 2050 Wage Loss-Temperature ratios was used. If calculating for 2051-2090 a year-weighted average of the 2050 and 2090 Wage Loss-Temperature ratio was used. When calculating for a year later than 2090, the 2090 Wage Loss-Temperature ratio was used. For 2064 and 2084, a year-weighted average was applied. These weights were calculated using equation (13).

$$(4)\quad \text{2064 year-weight for 2050} = 1 - (2064\text{-}2050)/(2090\text{-}2050)$$

With the appropriate Wage Loss-Temperature ratios and year-weighted averages completed, the 2064 and 2084 wage losses for the low and high emissions scenarios were calculated using equation (14).

$$(5)\ \ \text{2064 Wage losses} = \text{Temperature}_{2064} * ((\text{2064 year-weight for 2050} * \text{Wage Loss-Temperature Ratio}_{2050}) + (\text{2064 year-weight for 2090} * \text{Wage Loss-Temperature Ratio}_{2090})$$

Summary and Results

Ultimately, climate change is expected to have a multi-faceted impact on U.S. employment income throughout different industries and sectors. Although additional long-term health impacts from climate change risks can further jeopardize employment income, this analysis provides an overview of lost employment income due to unsuitable working conditions under extreme weather conditions. The following employment income losses were estimated in 2024 dollars.

Table 50. Lost Employment Income SSP1-2.6 Low Emissions Scenario (Millions of $2024).

	2024	2034	2044	2064	2084	2104
NE	$3,130	$4,042	$4,707	$4,944	$4,334	$4,219
SE	$7,759	$10,021	$11,669	$13,995	$14,782	$15,211
MW	$6,029	$7,786	$9,067	$11,060	$11,917	$12,326
NP	$392	$506	$589	$753	$854	$895
SP	$4,821	$6,227	$7,251	$11,595	$15,916	$17,375
SW	$2,313	$2,988	$3,479	$5,764	$8,102	$8,884
NW	$128	$166	$193	$223	$225	$228
US Total	$24,897	$32,155	$37,444	$47,199	$52,755	$55,076

Table 51. Lost Employment Income SSP3-7.0 High Emissions Scenario (Millions of $2024).

	2024	2034	2044	2064	2084	2104
NE	$2,820	$3,921	$5,023	$9,351	$16,540	$23,594
SE	$8,229	$11,441	$14,656	$25,508	$42,493	$59,822
MW	$5,880	$8,175	$10,472	$18,180	$30,210	$42,505
NP	$407	$566	$726	$1,335	$2,337	$3,326
SP	$5,209	$7,242	$9,277	$16,208	$27,096	$38,176
SW	$3,372	$4,687	$6,005	$11,475	$20,738	$29,714
NW	$193	$268	$343	$774	$1,570	$2,300
US Total	$25,967	$36,099	$46,243	$83,616	$131,127	$204,655

Income Changes for Employees in Regions of Interest and for by Persona

Applying the following methods to the aggregate income analysis, ICF was able to estimate the impacts of climate change on employment income by household type and by occupation. We note that our analysis likely underestimates the total effect due to the exclusion of economy-wide impacts that could affect earnings in sectors that are not directly climate sensitive, but that have climate-sensitive supply chains or that are sensitive to climate-driven decreases in GDP growth. In addition, the analysis does not assess decreased income associated with changes in precipitation patterns and storminess.

Impacts of Climate Change on Income by Household Type

First, we estimated the total costs to income by climate change scenario by analysis year for the United States, nationally and by region. See the previous section on total U.S. income losses. To estimate the income loss per person by analysis year nationally, we used the employed population estimates we derived in a previous section of our analysis (see the Employed Population section for more details). Table 52 presents our estimated total employment in the United States by analysis year.

Table 52. Estimated Total U.S. Employment by Analysis Year (Number of Employees).

Year	Total estimated employment – Scenario 1	Total estimated employment – Scenario 2
2024	159,184,488	159,184,488
2034	171,212,859	161,780,729
2044	182,204,690	161,311,687
2064	201,386,355	153,917,302
2104	214,807,528	121,609,984

Source: Federal Reserve Economic Data (FRED) (2024). “Employment Level”, CE16OV, retrieved fromhttps://fred.stlouisfed.org/series/CE16OV; U.S. Bureau of Labor Statistics (2023). “Employment Projections”, table 2.1, retrieved from: https://www.bls.gov/emp/tables.htm; ICF analysis, 2024.

ICF then estimated the change in employment at the regional level based on the states that belong to each region.[97] To do this, ICF used employment data by state from the U.S. BLS.[98] ICF calculated the national employment growth rates between analysis years based on the employment values in Table 52. Next, we applied these growth rates to the regional employment for each region of interest. Table 53 presents the estimated employment by region and analysis year.

Table 53. Estimated Total Employment by Region and Analysis Year (Number of Employees).

Year	Total estimated employment – Scenario 1[a]	Total estimated employment – Scenario 2 [a]
	Northeast[b]	
2024	31,893,000	31,893,000
2034	34,302,913	32,413,163
2044	36,505,154	32,319,190
2064	40,348,247	30,837,706
2104	43,037,212	24,364,857
	Southeast[c]	
2024	38,253,600	38,253,600
2034	41,144,136	38,877,502
2044	43,785,581	38,764,787
2064	48,395,124	36,987,843

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[97] The states that belong to each region are defined by US EPA. (2017) “Multi-Model Framework for Quantitative Sectoral Impacts Analysis: A Technical Report for the Fourth National Climate Assessment,” Table 28.2, page 209, retrieved from: https://www.epa.gov/sites/default/files/202103/documents/ciraii_technicalreportfornca4_final_with_updates_11062018.pdf.

[98] U.S. Bureau of Labor Statistics (n.d.). (2023) “Employment by state, seasonally adjusted”, retrieved from: https://www.bls.gov/charts/state-employment-and-unemployment/employment-by-state-bar.htm

2104	51,620,364	29,224,077
Midwest[d]		
2024	30,164,200	30,164,200
2034	32,443,481	30,656,167
2044	34,526,346	30,567,287
2064	38,161,120	29,166,110
2104	40,704,326	23,044,129
Southwest[e]		
2024	28,470,400	28,470,400
2034	30,621,693	28,934,742
2044	32,587,600	28,850,853
2064	36,018,271	27,528,355
2104	38,418,670	21,750,140

Notes:
[a] Future employment is calculated by applying the growth rate between the analysis year and the employment level for 2024. ICF assumed the employment level in December, 2023 reflects employment in 2024.
[b] The Northeast region contains the states: Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, and West Virginia.
[c] The Southeast region contains the states: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, and Virginia.
[d] The Midwest region contains the states: Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin.
[e] The Southwest region contains the states: Arizona, California, Colorado, Nevada, New Mexico, and Utah.
Source: U.S. Bureau of Labor Statistics (n.d.). "Employment by state, seasonally adjusted", retrieved from: https://www.bls.gov/charts/state-employment-and-unemployment/employment-by-state-bar.htm; ICF analysis, 2024

ICF estimated the income loss per person nationally in the U.S. by dividing the total national loss in income in each analysis year by its associated employment level (Table 52). ICF then calculated loss in each region by dividing the total loss by region by that region's associated level of employment (Table 53) by analysis year. Each region contains one city of interest to this analysis. Regional income losses are derived from the EPA's 2017 Climate Change Impacts and Risk Analysis (CIRA) project for the fourth National Climate Assessment[99] (see previous section estimating total regional and U.S. income impacts). Table 54 presents the changes in annual income per employee nationally and by region of interest.

Table 54. Changes in Annual Income per US Employee by Scenario, Analysis Year, and Selected Geography (2024$)[a].

Scenario	**Year**		
	2044	**2064**	**2104**
US (National)			
Scenario 1	-$205	-$235	-$255
Scenario 2	-$285	-$545	-$1,685

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[99] US EPA. "Multi-Model Framework for Quantitative Sectoral Impacts Analysis: A Technical Report for the Fourth National Climate Assessment," (2017), Table 28.2, page 209, retrieved from: https://www.epa.gov/sites/default/files/202103/documents/ciraii_technicalreportfornca4_final_with_updates_11062018.pdf.

Scenario	**Year**		
	2044	**2064**	**2104**
Northeast			
Scenario 1	-$130	-$125	-$100
Scenario 2	-$155	-$305	-$970
Southeast			
Scenario 1	-$265	-$290	-$295
Scenario 2	-$380	-$690	-$2,045
Midwest			
Scenario 1	-$265	-$290	-$305
Scenario 2	-$345	-$625	-$1,845
Southwest			
Scenario 1	-$105	-$160	-$230
Scenario 2	-$210	-$415	-$1,365
Notes: [a] Income losses are rounded to nearest 5th dollar value. Source: ICF analysis, 2024			

Impacts of Climate Change on Income by Persona

Several studies have investigated the impact of climate change and heat stress on earnings in the United States. These studies developed analytical models that quantitatively describe the impact of additional hot days (days with maximum temperatures above certain thresholds) on earnings. ICF utilized this information to quantify the relationship between additional hot days and earnings. Table 55 presents these estimates and their associated climate thresholds. For non-agricultural industries, the impact of an additional day above 32 degrees Celsius each year decreases annual earnings by 0.043 percent. The impact of hot days is greater for highly exposed industries which includes utilities, manufacturing, construction, agriculture, and transportation.[100] For the agricultural sector, an additional day above 30 degrees Celsius each year is estimated to decrease annual earnings by 0.076 percent. These authors estimated damages to US earnings as a whole and find that these damages are only statistically significant for the agricultural sector.[101] As a result, ICF reported this coefficient as the estimated impact of additional hot days per year on annual earnings in the agricultural sector. ICF used these coefficients so we could estimate income changes for each persona more precisely based on the industry in which they are employed.

Table 55. Loss in Annual Payroll Estimates by Source.

Type	Coefficient	Threshold	Data years	Source
Non-agricultural	-0.04%	Additional day > 32° C	1986 - 2011	Behrer et al. (2021)
Highly exposed industries (Non-agricultural)	-0.17%	Additional day > 32° C		

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[100] Behrer, A. P et al (2021). "Heat Has Larger Impacts on Labor in Poorer Areas." Environmental Research Communications, page 11, retrieved from: https://doi.org/10.1088/2515-7620/abffa3

[101] Deryugina, Tatyana, and Solomon, M. Hsiang (2014). "Does the Environment Still Matter? Daily Temperature and Income in the United States." National Bureau of Economic Research Working Paper No. 20750, tables 3 & A1, retrieved from: https://www.nber.org/papers/w20750

Type	Coefficient	Threshold	Data years	Source
Agricultural	-0.08%	Additional day > 30° C	1969-2011	Deryugina & Hsiang (2014)
Aggregate[a]	-0.06%	Additional day > 32° C	-	Behrer et al. (2021); Deryugina & Hsiang (2014)
Note: a. The aggregate value is an average of the non-agricultural and agricultural coefficients. This estimate does not exclude employment sectors that are predominately indoors. Source: Deryugina, Tatyana, and Solomon, M. Hsiang (2014). "Does the Environment Still Matter? Daily Temperature and Income in the United States." National Bureau of Economic Research Working Paper No. 20750, tables 3 & A1, retrieved from: https://www.nber.org/papers/w20750; Behrer, A. P et al (2021). "Heat Has Larger Impacts on Labor in Poorer Areas." Environmental Research Communications, supplemental information tables 1 & 5, retrieved from: https://doi.org/10.1088/2515-7620/abffa3				

ICF estimated the change in income by persona based on that persona's region and industry. ICF first estimated regional income (Table 54). ICF then calculated the ratio between each payroll loss coefficient and the average payroll loss coefficient in Table 55 to estimate how each industry is affected by climate change differently with respect to income loss. ICF then estimated the change in income by persona adjusting for the persona's industry and region. Table 56 presents the change in income by persona and scenario in 2024 dollar amounts.

Table 56. Change in Income by Sector Type and Scenario (2024$)[a].

Scenario	Year		
	2044	2064	2104
Personal A - Tampa, FL			
Scenario 1	-$735	-$805	-$820
Scenario 2	-$1,055	-$1,915	-$5,670
Persona B - Reno, NV			
Scenario 1	-$75	-$115	-$165
Scenario 2	-$150	-$300	-$985
Person C - Vinton, IA			
Scenario 1	-$340	-$370	-$390
Scenario 2	-$440	-$800	-$2,355
Persona D - Boston, MA			
Scenario 1	-$95	-$90	-$70
Scenario 2	-$110	-$220	-$700
[a] Income losses are rounded to nearest 5th dollar value. Source: ICF analysis, 2024			

Assumptions

The approach to estimating the effect of climate change on income relies on several assumptions. Overall, this analysis does not explicitly examine other channels by which climate change may impact income such as an increase in the incidence of natural disasters due to changes in storminess or precipitation, which can affect access by employees and customers to workplaces, among other things.

It also does not estimate impacts to income due to climate-related decreases in GDP growth or supply chain impacts – both of which pertain to job types that are less obviously climate sensitive.

To estimate the impacts of climate change on income generally for the United States, ICF assumed a constant annual employment to population ratio from 2024-2104 for each respective scenario. This is adjusted for population under each scenario and analysis year. The shares of the costs of climate change on income incurred by each region may differ from the U.S. average shares used in this analysis.

To estimate the impacts of climate change on income by persona, ICF used a coefficient that describes the relationship between income and days above 32 degrees Celsius.[102] For the agricultural sector, a threshold of 30 degrees Celsius was used.[103] ICF also assumed that these coefficients are static between 2024 and 2100.

Qualitative Impacts of Climate Change on Income

Climate change may have disproportionate impacts on income for low-income households. For instance, Behrer, et al. (2021) estimated that income losses for 2040 to 2050 in the richest 10 percent of counties would be 95 percent less than the poorest 10% of counties.[104] Lower-income households are often located in more exposed areas of the U.S. such as urban heat islands or isolated rural areas.[105] Additionally, low-income people usually work in sectors that are more exposed to climate change such as agriculture or construction.[106] Low-income households also often have less resources to adapt to climate change[107] which could lead to further reductions in income.

Summary

The key takeaways from this analysis include:

- Nationally, income losses by 2104 are estimated to be greater in the high scenario compared to the low scenario: the annual average loss in household income in the U.S. is estimated to be $255 by 2104 under the low scenario and $1,685 under the high scenario.
- By region, employment income losses by 2104 are estimated to be greater for the southeast, followed by the midwest, southwest, and northeast. By 2104, under the high scenario, losses to

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[102] Behrer, A. P et al (2021). “Heat Has Larger Impacts on Labor in Poorer Areas.” Environmental Research Communications, retrieved from: https://doi.org/10.1088/2515-7620/abffa3

[103] For the agriculture sector, a threshold of 30 degrees Celsius was used because that is the threshold that was used in the underlying study: Deryugina, Tatyana, and Solomon, M. Hsiang (2014). “Does the Environment Still Matter? Daily Temperature and Income in the United States.” National Bureau of Economic Research Working Paper No. 20750, tables 3 & A1, retrieved from: https://www.nber.org/papers/w20750

[104] Behrer, A. P et al (2021). “Heat Has Larger Impacts on Labor in Poorer Areas.” Environmental Research Communications, retrieved from: https://doi.org/10.1088/2515-7620/abffa3

[105] Gamble, Janet L. and Balbus, John (2016). " The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment" U.S. Global Change Research Program, Chapter 9: Populations of Concern, retrieved from: https://health2016.globalchange.gov/populations-concern

[106] Heal, Geoffrey, and Jisung Park (2016). “Reflections—Temperature Stress and the Direct Impact of Climate Change: A Review of an Emerging Literature.” Review of Environmental Economics and Policy, page 359, retrieved from: https://doi.org/10.1093/reep/rew007

[107] Martinich, Jeremy (2023). "Fifth National Climate Assessment" U.S. Global Change Research Program, Chapter 19: Economics, retrieved from: https://nca2023.globalchange.gov/chapter/19/

income are estimated to be about $2,045 in the southeast, $1,845 in the midwest, $1,365 in the southwest, and $970 in the northeast. These differences in losses are similar under the low scenario.

- By occupation, employment income losses are estimated to be greatest for non-agricultural highly exposed industries followed by the agriculture (which is also a highly exposed industry) and non-agricultural industries. For instance, people in highly exposed non-agricultural sectors can expect income losses about 2.77 times greater than the average US employee. People in the highly exposed agriculture sector can expect income losses about 1.28 times greater than the average US employee.
  The quantitative estimates of employment income loss provided here are underestimates. They do not explicitly include the impact of changes in storminess or precipitation on employment. They also do not directly address employment income losses due to climate-related decreases in GDP growth or supply chain impacts – both of which pertain to job types that are less obviously climate sensitive.

Climate Change Impacts to Investments

This section describes the methodology used to estimate the impact of climate change on the retirement income of a person born in 2024. Climate change has the potential to cause a decline in productivity, or the efficiency in transforming production input into goods and services.[108] The prospect of reduced investment returns in the future renders investment less attractive. This will evoke a response in investment behavior, which has the potential to impact many retirees through lost investment income. This analysis aims to take a data source for lost investment income due to climate change to interpolate estimates of the annual impacts of climate change on American retirement income from 2024-2104.

The methodology for calculating investment losses due to climate change uses a similar model to the one described in Baseline retirement savings methodology section for baseline retirement income. However, here the wage losses associated with climate change that we previously calculated are used. Additionally, a climate change-driven reduction in rate of return (RoR) is added from 2044-2104. This reduced RoR is from a Mercer study[109] that examines how climate change will affect the return on investments for a 2-degree Celsius warming scenario by 2100 and a 4-degree Celsius warming scenario by 2100. In our analysis, we use the findings from the Mercer study for the 2-degree scenario as a proxy for the SSP1-2.6 scenario and the 4-degree scenario as a proxy for the SSP3-7.0 scenario. The Mercer study provides RoR effects for a “growth portfolio” and a “sustainable growth portfolio” for 2030, 2050, and 2100. We used the mean RoR effect of both of these portfolios and then interpolated for our analysis years of 2024, 2034, 2044, 2064, and 2104 using the same temperature-weighted ratio methodology described in the Scaling Across Time and Climate Scenarios for Wage Losses section. Since the temperature estimates for SSP3-7.0 from our analysis in 2100 are 5.15 degrees Celsius warming by 2100, we extrapolated the data points from the Mercer Study to fit our warming scenario. We did this

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[108] Burk, M., Hsiang, S.M., E. Global Non-linear Effect of Temperature on Economic Production. (2015). *Nature.* Global non-linear effect of temperature on economic production - PubMed (nih.gov)

[109] Mercer. “Investing in a Time of Climate Change,” (2019). page 39, figure 11, retrieved from https://info.mercer.com/rs/521-DEV-513/images/Climate-change-the-sequel-2019-full-report.pdf.

by creating a ratio between the two (1.29 = 5.15/4) and applied it to the projected RoRs provided for the Mercer 4-degree warming scenario.

We calculate the climate change impacts on investment losses as how much less or more someone would accumulate over their lifetime in annual investment returns with the climate driven RoR effects if they don't increase the percentage of employment income invested, relative to the baseline scenario. As described in more detail in the Baseline retirement savings methodology section, the baseline retirement model assumes that the person will save 1x their salary by the age of 30, 3x by 40, 6x by 50, 8x by 60, and 10x by 67.[110] The baseline model then adjusts the percent of employment income invested within each of these age brackets to be constant, and so that the person's total savings will exactly hit their goal savings by the goal year.

To calculate investment losses for each climate scenario, we subtract the annual impacts on employment income for the person (as calculated in the Methodology for Impacts on Total U.S. and Regional Employment Income section) from their baseline age adjusted wage for each year of their working lifetime. As such they have less employment income per year and therefore less money to invest, relative to the baseline. We also account for the climate impacts on investment returns using the aforementioned Mercer climate driven RoRs. By setting the person's percent of employment income invested for each age bracket equal to the baseline for the two climate scenarios, we then estimate how much the person will either lose or gain in investment earnings relative to the baseline scenario.

In other words, we assume that the person does not increase the percentage of their employment income invested for retirement savings over their lifetime and we compute the difference in their cumulative annual investment returns from the baseline (no climate change) scenario and their annual returns under SSP1-2.6 and SSP3-7.0 with the climate change-driven employment income and RoR effects considered. Table 57. Annual Returns Considering Climate Change-Driven RoR below shows the climate driven RoRs for each scenario used in our analysis.

Table 57. Annual Returns Considering Climate Change-Driven RoR

Year	SSP1-2.6 Annual RoR
2044	0.08%
2064	-0.01%
2104	-0.05%
Year	**SSP3-7.0 Climate Driven RoR**
2044	-0.15%
2064	-0.21%
2104	-0.25%

Cumulative lifetime retirement savings are greater under SSP1-2.6 than the baseline scenario. This is because the additional 0.08% of returns from 2044-2064 under SSP1-2.6 create additional savings in the short term that, due to the power of compounding interest, end up outweighing the total cumulative savings in the baseline scenario by $26,325. The Mercer study indicates a positive effect on earnings in

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[110] Fidelity (2023). "How Much Do I Need to Retire? Fidelity," retrieved from: https://www.fidelity.com/viewpoints/retirement/how-much-do-i-need-to-retire.

the short run, because the study assumes transition opportunities under a low emission scenario where investors can target investment in mitigation and adaption solutions required for a transformative transition and gain a “low-carbon transition premium”. Cumulative lifetime retirement savings significantly decrease under SSP3-7.0 compared to the baseline scenario. This is because the negative climate effects on investment rate of return throughout the person’s lifetime reduce their savings every year, and those losses are magnified by the power of compounding interest. Additionally, the person experiences greater annual employment income losses under SSP3-7.0 which reduces the amount of money they are able to invest, leading to even lower investment returns. We find that under SSP3-7.0, the person will lose approximately $402,000 in investment earnings over their lifetime compared to the baseline scenario.

Table 58 below shows the total savings the person has at their goal savings phases (save 1x their salary by the age of 30, 3x by 40, 6x by 50, 8x by 60) and out to 2104, under the baseline scenario, the low climate scenario, and the high climate scenario. In the baseline scenario, the person has $774,673 left in total savings at the age of 80. Comparatively, they have $804,754 left in savings under the low climate scenario and $387,773 left in savings under the high climate scenario at the age of 80.

Table 58. Cumulative total retirement savings under each climate change scenario

Year	Baseline	SSP1-2.6	SSP3-7.0
2054	$104,833	$104, 951	$103,553
2064	$427,784	$429,891	$419,524
2074	$937,207	$940,584	$903,778
2084	$1,198,460	$1,205,118	$1,109,854
2104	$774,673	$804,754	$387,773

Table 59 shows the difference in cumulative annual investment returns for the person at their goal savings phases and out to 2104 for each climate scenario, relative to the baseline scenario. The numbers in Table 59 are the numbers we present in the main article. It is important to note that the difference in total savings relative to the baseline in Table 58 are slightly different than the cumulative annual investment return impacts presented in Table 59 for the person during their retirement years (after 2085). For example, under the high scenario, in 2104 the person will have approximately $387,000 less left in their saving compared to the baseline scenario, but over their lifetime they will earn $402,074 less in cumulative investment returns. We present the cumulative differences in annual investment returns, shown in Table 59, in the main article because they more completely capture the cumulative lifetime climate impacts on investment returns, versus just the difference in amount left at the age of 80.

Table 59. Difference in cumulative annual investment returns relative to the baseline under each climate scenario

Year	SSP1-2.6	SSP3-7.0
2054	$118.85	-$1,280
2064	$2,107	-$8,260

Year	SSP1-2.6	SSP3-7.0
2074	$3,376	-$33,430
2084	$6,658	-$88,605
2104	$26,326	-$402,074

Uncertainty

As mentioned previously, our analysis is subject to a significant amount of uncertainty. Although our analysis focuses on the impact to the average American consumer, the impact of climate change on investment earnings will be different for consumers with different income levels. Higher income individuals will experience a greater magnitude in investment losses, simply because they are investing larger amounts of money, but the burden of investment losses will be greater for low-income individuals. Ultimately, greater investment losses for consumers with relatively little retirement investment savings to begin with could force some retirees to run out of their savings faster than expected and leave them with no source of income for their retired years besides Social Security checks.

Commented [AD1]: @Milan, Alex
Can you help add in 1-3 paragraphs to describe the magnitude of the uncertainty, what the sources of that uncertainty are, and how it may vary from person to person for retirement income?

Our methodology for calculating investment losses involves several assumptions that provide a framework for projecting investment, but also create sources of uncertainty that are not addressed in our analysis. For example, we assumed that a person would start investing some of their employment income after their annual wage exceeded $40,000. The baseline retirement income model assumes a 7.0% annual rate of return for investments each year from 2044-2104, based on the historical average annual rate of return for a risk averse portfolio. The model also assumes that the person will save 1x their salary by the age of 30, 3x by 40, 6x by 50, 8x by 60, and 10x by 67 (See Baseline retirement saving methodology). These factors can be impacted by investor behavior, portfolio diversification, and even federal retirement reform. Life events, that can also be created and/or worsened by climate change, impact an individual's ability to consistently invest a portion of their employment income. Property damage, healthcare costs, and other costs that are often exacerbated by climate change, can also impact a person's ability to invest their employment income, manage risk, and allow their retirement saving to grow throughout their working life. Nonetheless, as the first summary of consumer-level impacts of climate change, the analysis team believes the information in this report provides useful estimates.

Methodology for Taxes and Public Spending

This section describes the methodology used to estimate the impact of climate change on the personal taxes of a person born in 2024. Climate change increases federal budget deficits, and therefore taxes, by reducing federal revenues and increasing federal expenditures. Climate change decreases tax revenues primarily through changes in the economy such as decreased household income and real estate values that affect the amount of federal revenues from income taxes, payroll taxes, and other sources.[111] Climate change increases government expenditures through a variety of ways, such as physical damages to our nation's infrastructure and healthcare expenditures, creating instability of certain subsidized

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[111] CBO. "Budgetary Effects of Climate Change and of Potential Legislative Responses to It," (2021). page 4, retrieved from: https://www.cbo.gov/publication/57175.

insurance programs, and accelerating instability that threatens global security.[112] By decreasing tax revenues and increasing government expenditures, climate change effectively increases the demand for government services while simultaneously decreasing the government's ability to fund such services. As such, achieving sustainable public budgets in a changing climate is expected to require additional revenues through increased taxes.

While there is evidence that suggests climate change will significantly impact taxes, many individual impacts have limited quantified data. Other impacts, such as law enforcement and military expenditure changes due to potential increases in crime and international conflict, are currently unquantified. This analysis aims to pull together different known data sources into one coalescent report to estimate the quantified impacts of climate change on American personal taxes from 2024-2104.

Government Expenditures

To estimate the impact of climate change on government expenditures, we used data from the Office of Management and Budget's (OMB) budget for fiscal year 2023[113] and 2024[114]. These OMB reports quantify the projected changes in annual expenditures from climate impacts for crop insurance, coastal disasters, healthcare, wildland fire suppression, and the National Flood Insurance Program (NFIP) for SSP2- 4.5 and SSP5- 8.5 out to mid-century and late-century dates. The mid-century and late-century dates vary across the assessed federal programs. Table 60 shows the years assessed for each government expenditure program.

Table 60. Years Assessed for Government Expenditure Programs.

Assessed Program	Mid-Century Year	Late-Century Year
Crop Insurance	The crop insurance analysis was only conducted for late century	2080
Coastal Disasters	2050	2075
Healthcare	2050	2100
Wildland Fire Suppression	2050	2090
NFIP	2050	2100

The OMB budget for fiscal years 2023 and 2024 builds off of previous analysis done by OMB initially in a 2016 preliminary assessment of the fiscal risks from climate change facing the federal government [115], which was then updated in a 2022 report[116]. The values found from the 2022 report were then

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[112] OMB. "Federal Budget Exposure to Climate Risk 2023," April 2022, page 277, retrieved from: https://www.whitehouse.gov/wp-content/uploads/2022/04/ap_21_climate_risk_fy2023.pdf.

[113] OMB. "Federal Budget Exposure to Climate Risk 2023," April 2022, table 21-2, page 282, retrieved from: https://www.whitehouse.gov/wp-content/uploads/2022/04/ap_21_climate_risk_fy2023.pdf.

[114] OMB. "2024 BUDGET EXPOSURE TO INCREASED COSTS AND LOST REVENUE DUE TO CLIMATE CHANGE," (2023). table 10-1, page 98, retrieved from: https://www.whitehouse.gov/wpcontent/uploads/2023/03/ap_10_climate_change_fy2024.pdf.

[115] OMB. "CLIMATE CHANGE: THE FISCAL RISKS FACING THE FEDERAL GOVERNMENT A Preliminary Assessment," November 2016, page 6, retrieved from: https://obamawhitehouse.archives.gov/sites/default/files/omb/reports/omb_climate_change_fiscal_risk_report.pdf.

[116] OMB. "AN ASSESSMENT OF THE FEDERAL GOVERNMENT'S FINANCIAL RISKS TO CLIMATE CHANGE," April 2022, table 1, page 3, retrieved from: https://www.whitehouse.gov/wp-content/uploads/2022/04/omb_climate_risk_exposure_2022.pdf.

incorporated into the OMB budget for fiscal year 2023 and updated again in the OMB budget for fiscal year 2024.

In addition to the data from OMB, we used data for the projected economic impact of climate change on Roads, Bridges, Railroads, Alaska Infrastructure, Urban Drainage, Municipal and Industrial Water Supply, and Water Quality as a proxy for estimating the impact of climate change on public infrastructure and water that is funded through taxpayer money. This data comes from the same 2017 CIRA report that we used for the employment income section of our analysis (see Methodology for Impacts on Total U.S. and Regional Employment Income section).[117] The report provided projections under SSP2- 4.5 and SSP5-8.5 for the years 2050 and 2090.

Scaling Across Time and Climate Scenarios for Government Expenditures

It is important to note that for our analysis, we assumed a worst-case scenario for the taxpayer for both scenarios where individual income tax, sales tax, and corporate income tax would increase to negate any government debt from climate change impacts to government expenses and tax revenues. The actual impacts on personal taxes for the consumer, however, could vary significantly. For example, instead of the worst-case scenario we assume, there could be a best-case scenario for the consumer where all impacts of climate change on government expenses and revenues are transferred to the federal debt and do not result in higher taxes for the consumer. As such, our quantified personal tax impacts could theoretically range from anywhere from zero dollars to the estimates we provide for the worst-case scenario. We chose to assume the worst-case scenario when providing estimates in our analysis to illustrate the total breadth of the potential climate impacts on consumer taxes.

To interpolate the increased expenditures data from the CIRA report for SSP3-7.0 for our analysis years of 2024, 2044, 2064, and 2104 we used the same linear interpolation methodology as described in the employment income section of this appendix (see Methodology for Impacts on Total U.S. and Regional Employment Income section).

This same methodology was replicated to interpolate the OMB data but adjusted slightly for the different dates shown in Table 60. Years Assessed for Government Expenditure Programs. earlier in this section. For example, the OMB data for the costs of coastal disaster to federal expenditures was given for the years 2050 and 2075.[118] To interpolate this data out to our desired dates (2024, 2034, 2044, etc.) we similarly used the 2050 cost-temperature ratio for interpolating costs in 2050 or earlier but used a weighted average of the 2050 and 2075 cost-temperature ratios for interpolating costs from 2051-2074, and then used the 2075 cost-temperature ratio for interpolating costs in 2075 or later. Overall, throughout our analysis we created a weighted average of cost temperature ratios of the upper bound and lower bound cost values and then multiplied that weighted average by the temperature in the given scenario and interpolation year to interpolate a cost value for SSP3-7.0 when possible. When there was not a lower bound and upper bound available, we used the cost temperature ratio of the closest year and multiplied that by the temperature in the given scenario and interpolation year. Table 61 below

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[117] US EPA. "Multi-Model Framework for Quantitative Sectoral Impacts Analysis: A Technical Report for the Fourth National Climate Assessment," May 2017, Table 28.2, page 209, retrieved from: https://www.epa.gov/sites/default/files/202103/documents/ciraii_technicalreportfornca4_final_with_updates_11062018.pdf.

[118] OMB. "Federal Budget Exposure to Climate Risk 2023," April 2022, page 280, retrieved from: https://www.whitehouse.gov/wp-content/uploads/2022/04/ap_21_climate_risk_fy2023.pdf.

shows our estimates for the total increase in government expenditures from climate impacts for SSP3-7.0.

Table 61. Change in Annual Expenditures of Government Programs for the high climate scenario (USD $2024 Billions).

SSP3-7.0						
Year	**2024**	**2034**	**2044**	**2064**	**2084**	**2104**
Coastal Disaster	12.97	18.03	23.10	52.58	90.59	120.42
Healthcare	0.71	0.99	1.27	4.10	9.82	17.67
Wildfire	1.04	1.44	1.85	3.61	6.62	9.52
Crop Insurance	0.52	0.72	0.93	1.34	1.79	2.38
NFIP	2.50	3.47	4.45	5.65	6.10	6.57
Roads	5.35	7.44	9.53	13.75	18.40	24.46
Bridges	1.04	1.44	1.85	1.99	1.36	1.28
Rail	1.08	1.50	1.92	3.27	5.34	7.48
Alaska Inf.	0.10	0.14	0.18	0.21	0.19	0.22
Urban Drainage	2.51	3.49	4.47	5.75	6.36	7.93
Water Supply	0.08	0.11	0.14	0.21	0.32	0.44
Water Quality	1.12	1.56	1.99	3.11	4.60	6.30
Total	**29.01**	**40.33**	**51.67**	**95.55**	**151.50**	**204.67**

To interpolate the total increase in government expenditures from climate impacts for SSP1-2.6, we used the same methodology as described above for scenario SSP3-7.0, with a couple caveats. A few of the assessed categories from the data we used from OMB and the CIRA report provided cost impacts that were extremely high for SSP5- 8.5 compared to the cost impacts for SSP2- 4.5. When replicating the same linear interpolation methodology for data like this to estimate cost impacts for SSP1-2.6, we calculated negative cost impacts for the assessed category for SSP1-2.6. This was the case for the coastal disaster, healthcare, and crop insurance categories. When this occurred, we assumed that the climate impact on the assessed category would be zero dollars. In other words, we placed a zero lower bound when interpolating for the climate change cost impacts on government expenditures for SSP1-2.6. As an example, for the crop insurance category (which provided data for SSP2- 4.5 and SSP5-8.5 for the year 2080 only) the given data was a 0.3 billion dollar cost impact under SSP2-4.5 and a $2.2 billion cost impact under SSP5-8.5. Due to the linear relationship of the given data, our linear interpolation calculation for crop insurance for SSP1-2.6 for 2080 then yielded -0.60 billion dollars. Instead of reporting this negative value, we assumed the cost would be zero dollars.

Another caveat for estimating the total increase in government expenditures from climate impacts for SSP1-2.6 was that for the bridges, railroads, urban drainage, and water supply categories from the CIRA data (for the years before 2050), we calculated cost impacts that were greater under SSP1-2.6 than under SSP3-7.0. This happened for the urban drainage category because the cost data from our data source (the CIRA report) for urban drainage for 2050 was actually greater for SSP2-4.5 ($4.3 billion) than for SSP5-8.5 ($3.7 billion). As such, when conducting our linear interpolation, we estimated a higher cost for urban drainage for SSP1-2.6 for the years 2024, 2034, and 2044 than in SSP3-7.0. In place of providing these higher costs, we instead used the same costs we estimated for SSP3-7.0 for the urban drainage category for the years 2024, 2034, and 2044 as we could not justify a credible reason for why urban drainage cost impacts would be greater under the lower climate scenario.

For the bridges, railroads, and water supply categories, we calculated a higher cost for SSP1-2.6 for some of the years before 2050 largely because the temperature in 2050 under SSP1-2.6 (2.016 degrees Celsius) was lower than the temperature in 2050 under SSP3-7.0 (2.411 degrees Celsius). As such, when calculating the cost temperature ratios that we used to estimate the cost impacts for SSP1-2.6, the denominator (temperature) was smaller for SSP1-2.6 than for SSP3-7.0. Therefore, when the data souce cost impacts directly from the CIRA report for SSP2-4.5 were only slightly smaller than for SSP5-8.5, this smaller denominator for SSP1-2.6 sometimes resulted in a larger cost temperature ratio for SSP1-2.6 compared to SSP3-7.0 which then led to a greater cost estimate under SSP1-2.6. This was further compounded when we interpolated for the year 2024 because the temperature for the year 2024 was higher under SSP1-2.6 (1.268 degrees Celsius) than the temperature under SSP3-7.0 (1.20 degrees Celsius). Therefore, when we multiplied the cost temperature ratio for 2050 for SSP1-2.6 (which may already have been greater than SSP3-7.0 for the reasons described above) by the temperature for SSP1-2.6 in the year 2024, in order to estimate the final cost impact, we were multiplying by a larger number compared to SSP3-7.0, which then yielded a higher cost. Again, this only occurred when the cost impacts for SSP2-4.5 and SSP5-8.5 provided from the CIRA report were relatively close. Specifically, this occurred only for the bridges category for the years 2024 and 2034, for the railroads category for the year 2024, and for the water supply category for the years 2024, 2034 and 2044. For each of these cases, we provided the cost estimates we calculated for SSP3-7.0 instead of these higher estimates as we could not credibly defend why these climate change cost impacts would be greater under the lower climate scenario. Please see the Methodology for Impacts on Total U.S. and Regional Employment Income section for more detail on the linear interpolation methodology we used.

Table 62 below shows our estimates for the total increase in government expenditures from climate impacts for SSP1-2.6.

Table 62 Change in Annual Expenditures of Government Programs for the low climate scenario (USD $2024 Billions).

SSP1-2.6						
Year	**2024**	**2034**	**2044**	**2064**	**2084**	**2104**
Coastal Disaster	0.00	0.00	0.00	0.00	0.00	0.00
Healthcare	0.00	0.00	0.00	0.00	0.00	0.00
Wildfire	0.13	0.17	0.20	0.22	0.21	0.21
Crop Insurance	0.00	0.00	0.00	0.00	0.00	0.00
NFIP	2.25	2.91	3.39	3.64	3.30	3.16
Roads	4.11	5.31	6.18	5.64	3.71	3.21
Bridges	1.04	1.44	1.71	1.37	0.58	0.36
Rail	1.08	1.42	1.65	2.42	3.10	3.34
Alaska Inf.	0.07	0.10	0.11	0.10	0.06	0.05
Urban Drainage	2.51	3.49	4.47	5.66	4.66	4.44
Water Supply	0.08	0.11	0.14	0.18	0.20	0.21
Water Quality	1.06	1.37	1.60	2.23	2.75	2.94
Total	**12.34**	**16.32**	**19.45**	**21.46**	**18.59**	**17.93**

Government Revenues

In our analysis, we also interpolated the projected impacts of climate change on tax revenues for our analysis years. To date, there are limited quantifiable projections of the impacts of climate change on tax revenue in the United States. To estimate tax revenue losses from climate impacts, we used a ratio from the OMB 2023 budget that federal revenues could be 7.1 percent lower annually by 2100 under a scenario in which climate change reduced U.S. GDP by 10.0 percent compared to a no-further-warming counterfactual.[119] We used this ratio of 10.0 percent GDP loss to 7.1 percent loss in federal tax revenue from OMB, the percent loss in GDP due to climate change impacts for SSP1-2.6 and SSP3-7.0 that we estimated in other sections of our analysis (see Methodology for Macroeconomic Burden Estimates section), the GDP without climate impacts data we estimated in other sections of our analysis (see GDP without climate impacts section), and a fixed percentage of U.S. tax revenue as 17% of GDP[120] to interpolate losses in federal tax revenue from climate impacts. This calculation is shown in the formula shown below using SSP3-7.0 as an the example scenario.

$$\textit{Loss in U.S. Tax Revenue}_{\textit{SSP3-7.0 in interpolated year}} = (7.1/10) * \%\ \textit{loss in GDP per capita}_{\textit{SSP3-7.0 in year interpolated year}} * 0.17 * \textit{GDP without climate impacts}_{\textit{interpolated year}} /100$$

Table 63 below shows our estimates for the total annual tax revenue losses from climate impacts for SSP1-2.6 and SSP3-7.0.

Table 63. Loss in US Tax Revenue (USD 2024 Billions).

	SSP1-2.6	SSP3-7.0
2024	6.76	32.47
2034	11.98	43.16
2044	23.92	114.34
2064	63.06	261.01
2084	114.39	472.92
2104	171.87	788.54

Personal taxes

To estimate the impact of climate change on total U.S. personal taxes for both climate scenarios, we summed up the absolute value of our estimates for the impact of climate change on government expenditures and government tax revenues described in the sections above to calculate the total U.S. tax increase from climate impacts for our analysis years. We then performed a linear polynomial smoothed fitting of that data to obtain an annual time series of the total U.S. tax increase from climate impacts from 2024-2104. To estimate climate impacts on personal taxes per worker, we then divided

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[119] OMB. "Federal Budget Exposure to Climate Risk 2023," April 2022, page 277, retrieved from: https://www.whitehouse.gov/wp-content/uploads/2022/04/ap_21_climate_risk_fy2023.pdf.

[120] CEIC Data. "US Tax Revenue: % of GDP, 1968 – 2022," 2023, "Key information about US Tax revenue" bulleted list, retrieved from: https://www.ceicdata.com/en/indicator/united-states/tax-revenue--of-gdp.

the total U.S. tax increase by the employed population time series under SSP1-2.6 and SSP3-7.0 for every year out to 2104 (see Employed Population section).

In our analysis, we assume that the government will only increase individual income taxes, sales taxes, and corporate taxes to make up for the climate induced losses in government tax revenue and increases in governmental expenses. In other words, we assume that the government will not increase social insurance taxes to make up for climate change-induced losses in government revenue. For our analysis, we wanted to isolate the climate impacts on taxes that are relevant to the average consumer which we assumed to be individual income tax and sales/excise tax. In other words, we wanted to exclude the estimated climate impacts on corporate income taxes from our analysis.

To exclude corporate income taxes from our estimates, we used data from OMB on annual total government revenues from 2018-2022.[121] ICF calculated the average percentage of total U.S. tax revenue (excluding social insurance taxes) that comes from corporate income taxes from 2018-2022 (12.22%). We then adjusted every value of the annual time series of tax increase per worker to exclude this 12.22% to derive our final annual time series of the impacts of climate change on personal taxes only (individual income taxes and sales taxes).

We find that under SSP3-7.0, the person will pay approximately $200,000 more in personal taxes over their lifetime compared to the baseline scenario. Under SSP1-2.6, the person will pay approximately $5,000 more in personal taxes over their lifetime compared to the baseline scenario

Other Assumptions

Due to the lack of quantitative analysis done to date on the impacts of climate change on personal taxes, we had to make several assumptions to address data gaps in our analysis. To estimate projected losses in U.S. tax revenue for our analysis, we used GDP loss as a proxy for federal revenue loss. This relies on difficult assumptions about the impact of economic losses on U.S. GDP. For example, while economic losses are commonly expressed as a percent of global output, some portion of those losses occur in the form of non-market losses (e.g., premature mortality or biodiversity loss) that may not directly translate into lost GDP—or Federal revenue.[122] As such, revenue loss estimates are likely to be significantly underestimated in our analysis.

To estimate U.S. tax revenue losses, we also made the following key assumptions:

- We assumed a constant ratio of the percent of federal revenue loss to the percent GDP loss[123].
- We assumed that percentage loss in GDP is equal to percentage loss in GDP per capita, in terms of units, because at a particular moment in time, population is constant.

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[121] OMB. "Historical Tables." The White House, 2024, Table 2.1 – Receipts by Source:1934-2028, retrieved from https://www.whitehouse.gov/omb/budget/historical-tables/.

[122] OMB. "CLIMATE CHANGE: THE FISCAL RISKS FACING THE FEDERAL GOVERNMENT A Preliminary Assessment," November 2016, retrieved from: https://obamawhitehouse.archives.gov/sites/default/files/omb/reports/omb_climate_change_fiscal_risk_report.pdf.

[123] OMB. "Federal Budget Exposure to Climate Risk 2023," April 2022, page 277, retrieved from: https://www.whitehouse.gov/wp-content/uploads/2022/04/ap_21_climate_risk_fy2023.pdf.

- We assumed that the value of U.S. tax revenue as a percentage of GDP was equal to 17.0%, the average from 1968-2022 according to CEIC data[124], for all years in our analysis.

Data Gaps and Qualitative Effects

There are several anticipated impacts of climate change on government expenditures and revenues that are not modeled in this assessment. Data limitations restricted us from estimating the quantitative effects of climate change, for our given scenarios and time period, on all anticipated impacts of climate change on taxes. Some of the excluded impacts of climate change on government expenditures in our analysis include, but are not limited, to those listed in Table 64 below.

Table 64. Excluded Impacts of Climate Change on Government Expenditures in our Analysis.

Government program	Climate Change Impact
National Security	Increasing temperatures, changing precipitation patterns, and more frequent, intense, and unpredictable extreme weather conditions caused by climate change are likely to contribute to political, economic, and social instability in regions around the globe. This instability will likely exacerbate existing risks, create new challenges, and increase spending for Department of Defense (DOD) missions, plans, and installations.[125]
Ecosystem Services and Biodiversity	A 2022 University of Chicago study projects committed spending for the Endangered Species Act will reach $4.3 billion at 2°C warming and $21.2 billion at 5°C warming.[126]
Federal Property and Resource Management	Using the Federal Real Property Profile Management System (FRPP MS), OMB and FEMA assessed flood risks to Federal facilities and inundation risk at coastal facilities. The assessment identified over 40,000 individual Federal buildings and structures with a total combined replacement cost of $81 billion (2020$) located in the current 100-year floodplain. Approximately 160,000 federal structures, with a total replacement cost of $493 billion (2020$) were also identified within the current 500-year floodplain. OMB and NOAA also identified 10,250 individual Federal buildings and structures, with a combined replacement cost of $32.3 billion, that would be inundated or severely affected by typical high tide under an eight-foot sea-level rise scenario and 12,195 Federal buildings and structures, with a combined replacement cost of over $43.7 billion, under a ten-foot sea-level rise scenario.[127]
Housing and Mortgage Risks	Through increased frequency of extreme weather events, climate change will bring increased financial risks to the housing sector and to the Federal Government in its role as a guarantor of mortgages and mortgage-backed securities.[128]
Agriculture	Extreme weather events such as drought, flooding, and wildfires can cause reduced crop yields and higher food prices affecting food assistance programs and

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[124] CEIC Data. "US Tax Revenue: % of GDP, 1968 – 2022," 2023, "Key information about US Tax revenue" bulleted list, retrieved from: https://www.ceicdata.com/en/indicator/united-states/tax-revenue--of-gdp.

[125] OMB 2023

[126] Moore, Frances C., Arianna Stokes, Marc N. Conte, and Xiaoli Dong. "Noah's Ark in a Warming World: Climate Change, Biodiversity Loss, and Public Adaptation Costs in the United States." *Journal of the Association of Environmental and Resource Economists* 9, no. 5 (September 2022), page 1002, retrieved from: https://doi.org/10.1086/716662.

[127] OMB. "Federal Budget Exposure to Climate Risk 2023," April 2022, page 283, retrieved from: https://www.whitehouse.gov/wp-content/uploads/2022/04/ap_21_climate_risk_fy2023.pdf.

[128] OMB. "Federal Budget Exposure to Climate Risk 2023," April 2022, page 284, retrieved from: https://www.whitehouse.gov/wp-content/uploads/2022/04/ap_21_climate_risk_fy2023.pdf.

	agricultural subsidies. In addition to the crop insurance subsidies evaluated in our analysis, climate change is also expected to significantly impact farm bill disaster programs and emergency disaster-related spending for agriculture.[129]
Native American Relocation and Protection Costs	A 2020 study by the Bureau of Indian Affairs suggests there will be $3.45 billion in relocation and infrastructure investment needs for Alaskan tribal communities and $1.37 billion for the Contiguous 48 States Tribes over the next 50 years.[130]
Property Tax Revenues	Shi and Varuzzo 2020, find that sea level rise will decrease property tax revenues significantly in some coastal cities. Specifically, they project that three feet of sea level rise threatens 1.4% ($104 million) of current property taxes of 89 coastal municipalities in Massachusetts.[131]

Summary

Ultimately, climate change is expected to impact government expenditures and revenues, leading to an increase in taxes. As emphasized previously, this is not a comprehensive quantitative analysis of all the potential impacts of climate change on U.S. taxes and several broad assumptions were made in order to get quantified estimates for our assessed impacts. The total costs of climate change to the Federal Government are expected to be larger than those which are quantified in our analysis. As research advances, more federal programs may be incorporated into future analysis of climate-related financial risks.[132]

Methodology for Macroeconomic Burden Estimates

The economic impacts of climate change are currently being felt directly to individuals and economy sectors, and indirectly from market and government adjustments to direct changes. The exact amount of future economic impacts from climate change are uncertain due to dependence on greenhouse gas emissions and mitigation efforts. However, projections show the impacts to be more significant and apparent as climate change advances. Annual U.S. GDP is expected to slow by roughly by 0.13 percentage points for each 1◦F increase in global surface temperature.[133] This analysis identifies GDP data across different climatic impact scenarios and calculates the GDP per capita impact over the lifetime of a person born in 2024.

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[129] Taxpayers for Common Sense. "Paying the Price: Taxpayers Footing the Bill for Increasing Costs of Climate Change," June 2023, page 17, retrieved from: https://www.taxpayer.net/wp-content/uploads/2023/06/Taxpayer-Costs-for-Climate_Report.pdf.

[130] Department of Interior, Bureau of Indian Affairs. "The Unmet Infrastructure Needs of Tribal Communities and Alaska Native Villages in Process of Relocating to Higher Ground as a Result of Climate Change," 2020, page 5, retrieved from: https://www.bia.gov/news/unmet-infrastructure-needs-tribal-communities-and-alaska-native-villages-process-relocation

[131] Shi, Linda, and Andrew M. Varuzzo. "Surging Seas, Rising Fiscal Stress: Exploring Municipal Fiscal Vulnerability to Climate Change." *Cities* 100 (May 1, 2020): page 4, retrieved from: https://doi.org/10.1016/j.cities.2020.102658.

[132] OMB. "Federal Budget Exposure to Climate Risk 2023," April 2022, page 287, retrieved from: https://www.whitehouse.gov/wp-content/uploads/2022/04/ap_21_climate_risk_fy2023.pdf.

[133] Hsiang, S., S. Greenhill, J. Martinich, M. Grasso, R.M. Schuster, L. Barrage, D.B. Diaz, H. Hong, C. Kousky, T. Phan, M.C. Sarofim, W. Schlenker, B. Simon, and S.E. Sneeringer. (2023). Ch. 19. Economics. In: *Fifth National Climate Assessment*. Crimmins, A.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, B.C. Stewart, and T.K. Maycock, Eds. U.S. Global Change Research Program, Washington, DC, USA. https://doi.org/10.7930/NCA5.2023.CH19

Data Collection

To quantify the climatic impacts on GDP, data was gathered from a peer-reviewed study (Kahn et al. 2021) published in *Energy Economics*. The study used a stochastic growth model to determine the effect of temperature and precipitation deviations on GDP per capita growth for 174 countries, including the United States, from 1960 to 2014. Additionally, the study performed a counterfactual analysis investigating the effect of global annual temperature increases on GDP per capita for the same countries from 2015 to 2100.[134]

The exact increase in global annual temperature corresponds with the appropriate Representative Concentration Pathways (RCP) scenarios established by the Intergovernmental Panel on Climate Change (IPCC). For example, SSP5-8.5 equates to an increase in average global temperature of 0.04◦C per year. The data was reported as a percent loss in GDP per capita, using PPP-GDP as weighted averages for the years 2030, 2050, and 2100.[135] Due to the purpose of analyzing impacts by SSP1-2.6 and SSP3-7.0, the counterfactual analysis results were used in this analysis. The study published the results for the United States at RCP 2.6 and RCP 8.5 at varying levels of *m*, where *m* is the speed with which the historical temperature norms change and how fast countries adapt to global warming. For this analysis, the scenario m=30 was chosen to represent a middle scenario of countries response to higher temperatures as the norm. Table 65 shows the data used for the analysis.

Table 65. Percent Loss in GDP Per Capita for the United States under the RCP 2.6 and RCP 8.5 Scenarios.

Year	SSP1-2.6	SSP5-8.5
2030	0.2	1.2
2050	0.6	3.77
2100	1.88	10.52

Kahn et al (2021). "Long-term macroeconomic effects of climate change: A cross-country analysis." Energy Economics, page 12, retrieved from: https://doi.org/10.1016/j.eneco.2021.105624

Data Analysis

With the assumption of linearity between temperature and GDP per capita over time, the data was both interpolated and extrapolated to fit the needed RCP and year parameters of this report. It is also assumed that there is linearity between the SSP-RCP scenarios, ranging from low to high emission scenarios. The following sections describe the methodology to interpolate the missing values.

Interpolation for SSP1-2.6 and SSP3-7.0

This report analyzes the impact of climate change at a low (SSP1-2.6) and high (SSP3-7.0) emission scenario. To calculate the percent loss in GDP per capita for the, an interpolation was conducted using the known values of RCP 2.6 and RCP 8.5. The formula shown below was applied to calculate RCP-7.0 for the years 2030, 2050, and 2100. Table 66 shows the calculated values.

$$\%\ Loss_{7.0\ \text{in year}\ x} = ((7.0 - 2.6) / (8.5 - 2.6)) * (\%Loss_{8.5,\ Year\ X} - \%\ Loss_{2.6,\ Year\ X}) + \%\ Loss_{2.6,\ Year\ X}$$

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[134] Kahn et al (2021). "Long-term macroeconomic effects of climate change: A cross-country analysis." Energy Economics, page 12, retrieved from: https://doi.org/10.1016/j.eneco.2021.105624

[135] Kahn et al (2021). "Long-term macroeconomic effects of climate change: A cross-country analysis." Energy Economics, page 12, retrieved from: https://doi.org/10.1016/j.eneco.2021.105624

Table 66. Percent Loss in GDP Per Capita for the United States under the SSP3-2.6, SSP3-7.0, and SSP5-8.5 Scenarios.

Year	SSP1-2.6	SSP3-7.0	SSP5-8.5
2030	0.2	0.945763	1.2
2050	0.6	2.964068	3.77
2100	1.88	8.32339	10.52

Interpolation for Years 2034, 2044, 2064, and 2104

This report analyzes the impact of climate change on a child born in 2024 at ages 10, 20, 40, and 80 which correspond with the years 2034, 2044, 2064, 2084, and 2104. To interpolate for these missing years, a loss/temperature ratio was calculated for each year (2030, 2050, and 2100) shown in The formula shown below.

$$\%\ \textit{Loss/Temp Ratio}_{\textit{RCP, Year}} = \%\ \textit{Loss}_{\textit{RCP, Year}} / \%\ \textit{Loss}_{\textit{RCP, Year}}$$

Next, each year to be interpolated was assigned a year-weighted average for better accuracy. For years in between 2030 and 2050, a year-weighted average of the 2050 and 2090 GDP per capita loss/temperature ratio was used. For years between 2050 and 2100, a year-weighted average of the 2050 and 2100 GDP per capita loss/temperature ratio was used. Finally for years after 2100, the data was extrapolated using only the 2100 weighted average and GDP per capita loss/temperature ratio. The weight calculations for every year scenario are shown in Table 67.

Table 67. Year-Weighted Formulas and Results.

Year and Year Weighted	Weight Equation	Final Weight
2034 year-weight for 2030	= (2050-2034) / (2050-2030)	0.8
2034 year-weight for 2050	= 1 - 2034 year-weight for 2030	0.2
2044 year-weight for 2030	= (2050-2044) / (2050-2030)	0.3
2044 year-weight for 2050	= 1 - 2044 year-weight for 2030	0.7
2064 year-weight for 2050	= (2100-2064) / (2100-2050)	0.72
2064 year-weight for 2100	= 1 - 2064 year-weight for 2050	0.28
2084 year-weight for 2050	= (2100-2084) / (2100-2050)	0.32
2084 year-weight for 2100	= 1 - 2084 year-weight for 2050	0.68
2104 year-weight for 2100	= 1	1

Since all the needed components for the interpolation have been calculated, the 2034, 2044, 2064, 2084, and 2100 percent loss in GDP per capita for SSP1-2.6 and SSP-7.0 can be found using the following formula that shows am example of the calculation for 2034.

$$\begin{gathered}\textit{2034 \% Loss in GDP per capita}_{\textit{SSP- RCP}} = \\ \textit{2034 year-weight for 2030} * (\textit{2024 Baseline Temperature}_{\textit{SSP-RCP, 2034}} / \textit{2024 Baseline Temperature}_{\textit{SSP-RCP, 2030}}) \\ * \textit{\% Loss in GDP per capita}_{\textit{Year 2030}}) + \textit{2034 year-weight for 2050} * (\textit{2024 Baseline Temperature}_{\textit{SSP-RCP, 2034}} \\ / \textit{2024 Baseline Temperature}_{\textit{SSP-RCP, 2050}}) * \textit{\% Loss in GDP per capita}_{\textit{Year 2050}})\end{gathered}$$

Finally, to get the total impact on GDP per capita in USD, the final percent loss values were applied to the estimated GDP per capita without climate impact data.[136]

Results and Discussion

Table 68 shows the quantified results for projected impacts to GDP per capita under two different emissions scenarios in 2034, 2044, 2064, 2084, and 2104 expressed in percent loss in annual 2024 USD. Table 69 shows the quantified results in USD. The caveat in this methodology is having limited data points for the interpolation, lowering the potential accurateness of this analysis. This is not a comprehensive quantitative analysis of all the potential impacts of climate change on GDP, as it only utilizes temperature data and not specific damage from natural hazards.

Table 68. Percent Loss in GDP per capita.

Year	SSP1-2.6	SSP3-7.0
2034	0.2745	0.9895
2044	0.4753	2.2722
2064	0.9897	4.0965
2084	1.4836	6.1331
2104	1.8991	8.7130

Table 69. US GDP per capita with Climatic Impacts (USD).

Year	SSP1-2.6	SSP3-7.0
2034	96,384.77	105,688.15
2044	104,263.87	120,683.44
2064	118,824.20	157,157.35
2084	134,416.25	204,314.55
2104	156783.16	268,935.96

SSP1-2.6 Summary

In the main report, we discuss the impacts of climate change on net income and the cost of living under the high climate scenario (SSP3-7.0) but not the low climate scenario (SSP1-2.6). In this section of the appendix, we discuss our quantitative estimates for the impacts of climate change on net income and the cost of living under SSP1-2.6 for a person born in 2024.

Climate Impacts to the Average American Basket of Goods

Even under a best-case low emissions scenario, climate change is expected to impose significant costs on the average American consumer. By 2044, escalating storms and floods could inflict an average cost of $830 per year in weather-related damages on residential properties and an additional $3,100 by the end of the century, affecting both homeowners and renters, as landlords may transfer some costs through higher rents. At the same time, the rising frequency of heavy rainfall may result in increased

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[136] See GDP without climate impacts section.

transportation-related costs in the form of more frequent and hazardous vehicle accidents. By 2104, these could contribute to an annual average increase in vehicle crash costs of $60 for drivers. Healthcare expenses also stand to rise, with respiratory diseases estimated to be 3 percent more prevalent by the end of the century due to climate factors, resulting in average annual healthcare costs of roughly $3,200. Moreover, disruptions to agriculture could drive up food prices by 3 percent - a major hit to consumer budgets that would disproportionately impact lower income and single-parent families, some of whom may end up spending up to 16 percent of their income on food alone. Overall, lifetime costs due to climate change for a person born in 2024 under an optimistic, low emissions scenario will amount to a total of $172,700.

Climate Impacts to Net Income

Due to an increase in retirement income relative to the baseline, the person born in 2024 is expected to have a slight increase in lifetime net income under SSP1-2.6 relative to the baseline. At the beginning of their working lifetime, their net income is lower under SSP1-2.6 relative to the baseline as their gains in retirement savings are outweighed by their decreases in employment income and increases in taxes caused by climate change. Because of this, by age 40 they experience a cumulative $4,470 decrease in net income relative to the baseline. As the person gets older, however, their gains in retirement income relative to the baseline begin to overtake their losses in employment income and increases in taxes and they begin to experience a cumulative gain in net income relative to the baseline. This inflection point begins in 2080, or age 56 for the person. Over their lifetime, the person born in 2024 will experience a total cumulative increase of $11,383 in net income under the low climate change scenario. The following sections describe the climate impacts to the different components of net income (employment income, retirement savings, and personal taxes) under SSP1-2.6.

Employment Income

Under SSP1-2.6, climate change is estimated to negatively impact employment income. By the age of 40, the person born in 2024 is expected to have lost a cumulative amount of $4,677 in employment income. Overall, lifetime losses in employment income due to climate change for a person born in 2024 under the low emissions scenario will amount to a total of $9,700. Losses per employee are also expected to vary by region and industry. Additionally, employees are expected to experience higher losses in earnings in regions like the southeast and midwest compared to others like the northeast. For instance, in the midwest, the annual loss per employee is expected to be $305 whereas annual loss per employee in the northeast is estimated to be $100. Losses per employee are also estimated to differ by industry. We estimated that a person in the highly exposed non-agricultural sector and the highly exposed agricultural sector can expect income losses about 2.77 and 1.28 times greater than the average US employee. For instance, a person who works in construction in Tampa, FL can expect annual income losses under SSP1-2.6 of $820 by 2104 and a person who works as a nurse in Boston, MA can expect annual income losses of $70 by 2104. These estimates of income loss per employee are underestimates as they do not explicitly include the potential impacts of other weather changes (e.g., precipitation) on income. Moreover, these estimates do not consider the potential impacts related to climate-related supply chain and GDP growth decreases that may occur under SSP1-2.6.

Impacts to Investments

Cumulative lifetime retirement savings are greater for a person born in 2024 under SSP1-2.6 than the baseline scenario. This is because the additional 0.08% Climate ROR from 2044-2064 under SSP1-2.6 in our retirement model (see section on Climate Change Impacts to Investments for more detail on the model methodology), creates additional savings in the short term that, due to the power of compounding interest, end up outweighing the total cumulative savings in the baseline scenario. The Mercer study[137] that we used this 0.08% ROR value from indicates a positive effect on earnings in the short run, because the study assumes transition opportunities under a low emission scenario where investors can target investment in mitigation and adaption solutions required for a transformative transition and gain a "low-carbon transition premium".

Under SSP1-2.6, by age 40, the person is expected to have gained $2,107 more in retirement savings relative to the baseline. By age 80, they are expected to have gained $26,325 more in retirement savings relative to the baseline.

Personal Taxes

It is important to re-emphasize that for our analysis, we assumed a worst-case scenario for the taxpayer under SSP1-2.6 and SSP3-7.0 where individual income tax, sales tax, and corporate income tax would increase to negate any government debt from climate change impacts to government expenses and tax revenues. The actual impacts on personal taxes for the consumer, however, could vary significantly. We chose to assume the worst-case scenario when providing estimates in our analysis to illustrate the total breadth of the potential climate impacts on consumer taxes.

Under SSP1-2.6, by age 40, the person is expected to have paid $1,910 more in taxes relative to the baseline. By age 80, they are expected to have paid $5,212 more in taxes relative to the baseline.

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[137] Mercer. "Investing in a Time of Climate Change," (2019). page 39, figure 11, retrieved from https://info.mercer.com/rs/521-DEV-513/images/Climate-change-the-sequel-2019-full-report.pdf.