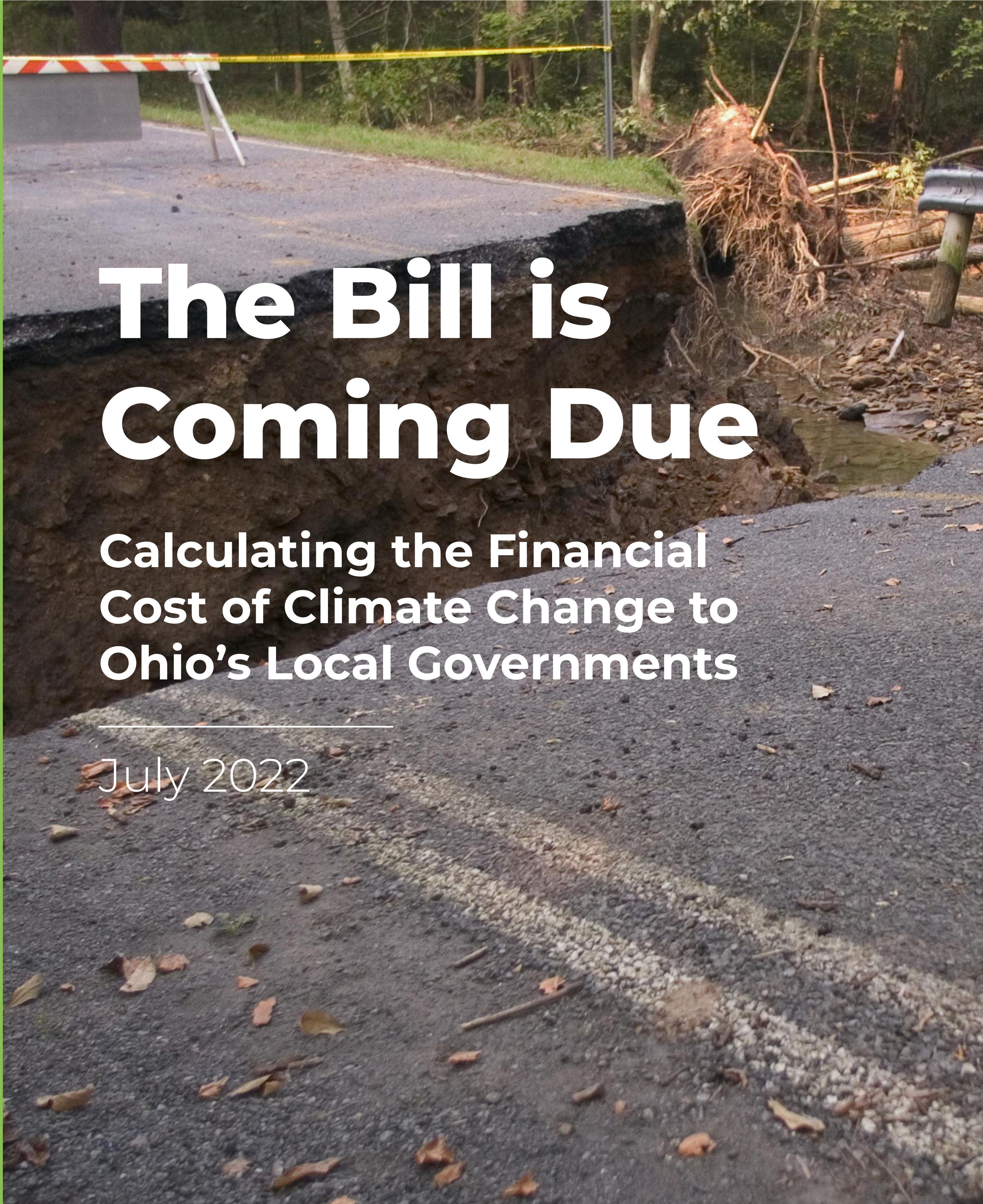

The Bill is Coming Due

Calculating the Financial Cost of Climate Change to Ohio's Local Governments

July 2022

Power A Clean Future Ohio
LOCAL COMMUNITIES LEADING THE WAY

Ohio Environmental Council

Scioto Analysis
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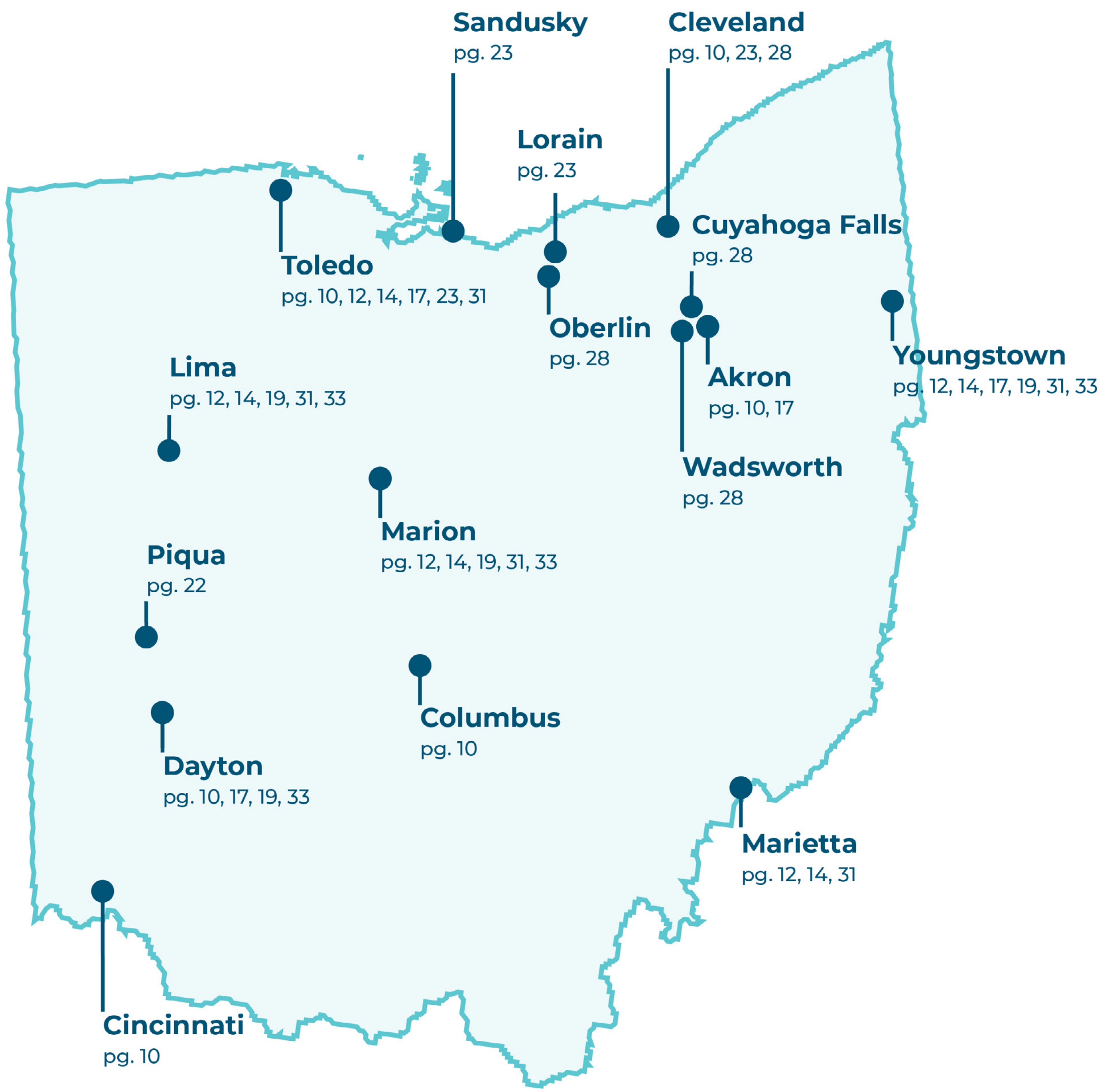

Executive Summary

From modernizing infrastructure and ensuring public safety, to improving school systems and tackling the opioid crisis, Ohio's local governments shoulder the costs of many critical public policy issues. Underlying each of these diverse and complicated issues is one big question: what will it cost?

Municipal officials already grappling with difficult budget decisions now have an additional challenge to add to their strained financial resources: climate change. Communities across Ohio have been coping with increasing temperatures, flooding, erosion, and climate-related extreme weather events for years. These climate damages are projected to only intensify in approaching decades, generating new costs associated with climate-driven disaster recovery and adaptation, as well as creating a major strain on already overstretched taxpayers and cash-strapped local governments. Unless we see drastic changes at every level of government to address carbon emissions in the next few years, these impacts will only continue to worsen — and the cost to address them will skyrocket.

The financial burden that climate change is placing on municipal governments is not well understood. This study aims to address this knowledge gap by assessing a subset of climate impacts that will create significant costs for local governments in Ohio. In total, our analysis identified 50 unique climate impacts that Ohio municipalities will have to address across the range of their mandates of infrastructure provision, public health services, housing, public safety, and more.

We estimate that the state of Ohio will need to increase municipal spending between $1.8 billion to $5.9 billion per year by midcentury in order to adapt to the challenges of a worsening climate crisis (Table 1).

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This represents a 26 to 82 percent increase of current spending levels for environment and housing programs for local governments in Ohio over a 2019 baseline, for just 10 of the 50 climate impacts identified in Ohio. Policymakers should know that these costs will not instantly appear in mid-century, but in most cases will start to accumulate this decade and steadily increase until they reach the projected midcentury estimates.

Table 1. Annual costs of climate change for major impacts on local governments expected by midcentury

Impact	Low-End Estimate	High-End Estimate
A/C Installation	$1.4 million	$6.8 million
Electrical Costs	$5.4 million	$79 million
Cool Roofing	$0	$4.6 million
Cooling Centers	$52 million	$590 million
Road Repair	$170 million	$1 billion
Drinking Water Treatment	$580 million	$2.2 billion
Storm Recovery	$35 million	$78 million
Power Lines	$140,000	$18 million
Stormwater Management	$140 million	$150 million
Elevating Roads	$860 million	$1.7 billion
Total	**$1.8 billion**	**$5.9 billion**

Our analysis provides a conservative estimate of the additional costs that municipalities can expect to incur due to climate change. Many of the costs of climate change are expressed in 2021 dollars, which means that simple inflation may drive these costs up on their own. The monetized amounts represent only 10 of the 50 different impacts addressed in this report. Monetization of the other 40 impacts would significantly increase the overall climate costs reflected here, but are hard to calculate on a statewide basis. In other words, the total increase in annual spending by municipal governments due to climate change is certainly higher, and likely much higher than this report reflects.

So, what can local governments do to address this problem? First, they could raise local taxes to cover some of these costs — never a popular option. Second, they could request funding from the federal government, but the federal government has limited resources when compared to the scope of climate impacts nationally. Both of these policy options rely on taxpayers to pick up the entire tab for climate costs even though taxpayers are not responsible for the climate crisis that Ohio municipalities are currently facing. Instead of relying on taxpayers to bear these costs, policymakers could consider alternative funding sources, such as holding accountable the corporations most responsible for causing and exacerbating climate change, and ensuring they pay their fair share of the costs of adaptation and resilience, just as many Ohio communities have held opioid manufacturers accountable for the costs of the opioid crisis.

This report is divided into five sections. The first section highlights four different costs associated with cooling public buildings in the face of more extreme heat days. Section two addresses the cost to repair roads damaged by increased incidents of severe weather. Section three estimates the cost to protect drinking water from greater prevalence of harmful algae blooms. Section four projects recovery and adaptation costs related to heavier precipitation. The fifth section estimates total statewide climate costs that municipal governments in Ohio can expect to incur by midcentury. The report concludes with policy options for local policymakers tasked with securing funding to cover these costs. The Appendix lists and describes the nature and costs of an additional 40 climate change impacts that will require new spending for local governments by midcentury.

Unless otherwise noted, all estimates in this analysis are based on the RCP 4.5 scenario. The RCP 4.5 climate scenario predicts that temperature will rise between 2 to 3 degrees Celsius before 2100 assuming a range of technologies and strategies for reducing greenhouse gas emissions are employed.[1]

1 Thomson, Allison M., et al. "RCP4.5: a pathway for stabilization of radiative forcing by 2100." Climatic Change 109, no. 1 (2011): 77-94.

1. Cooling

Climate change has caused an increase in the number of hot days per year, significantly lengthening the summer season in the Northern Hemisphere.[2] According to a 2019 report by the Union of Concerned Scientists, **days over 90 degrees in Ohio counties will likely triple from the historical average** of 10-20 days per year to 30-70 days per year by midcentury (2036-2050), even under conditions of rapid action to mitigate climate change.[3]

FrameAngel/Shutterstock.com

2 Wang et al, "Changing Lengths of the Four Seasons by Global Warming," Advancing Earth and Space Science, February 2021, Available Online: http://hjp.lzu.edu.cn/hjpnew/upload/files/20210510/87096f0c5ef94a039fa105da60c33c5c.pdf

3 "Killer Heat in the United States: The Future of Dangerously Hot Days," Union of Concerned Scientists, Available Online: https://ucsusa.maps.arcgis.com/apps/MapSeries/index.html?appid=e4e9082a1ec343c794d27f3e12dd006d

Public health researchers have found that heat exposure has adverse impacts on human health, productivity, and learning rates. According to a 2018 Harvard study, cumulative heat exposure reduces cognitive performance and academic achievement in schools, and these harms fall disproportionately on low-income students and students of color.[4] Overheating and its associated health impacts do not just present a risk to students, but to anyone living and working in buildings without reliable air conditioning.[5]

Hotter days mean higher costs to keep schools and public buildings at a safe and comfortable temperature for students and workers. Higher electrical costs, roofing improvements, and new air conditioning installation are just some of the related costs that Ohio municipalities must confront within the next decade. These costs are examined in more detail below.

New AC Installation in Schools

The threshold at which schools typically install air conditioning is 32 school days above 80 degrees Fahrenheit, according to a 2021 analysis from the Center for Climate Integrity and Resilient Analytics, which examined engineering protocols, peer-reviewed studies on the relationship between heat and learning, and actual practice in school systems across the country.[6] The report found that by 2025, school districts across Ohio are expected to experience between 11-15 additional days above 80 degrees while still in session compared to a baseline of 25-31 days in 1970.[7]

Despite higher temperatures and longer summers, many school districts in Ohio are still not equipped with air conditioning. Without the ability to maintain a safe and productive environment for students, dozens of Ohio schools have had to shut down on hot days.[8] As of August 2021, more than a dozen schools in the Columbus City School district still lacked air conditioning.[9] This represents 11 percent of the schools in the district.[10]

The Ohio Department of Education classifies the Columbus City School district as "urban" and "very high student poverty."[11] If the ratio of schools lacking air conditioning is the same

4 Goodman et al, "Heat and Learning," National Bureau of Economic Research, May 2018, Available Online: https://scholar.harvard.edu/files/joshuagoodman/files/w24639.pdf

5 Lomas, Kevin J. and Stephen M. Porritt, "Overheating in buildings: lessons from research," Building Research & Information, November 2016, Available Online: https://www.tandfonline.com/doi/pdf/10.1080/09613218.2017.1256136

6 LeRoy, Sverre et al, "Hotter Days, Higher Costs: The Cooling Crisis in America's Classrooms," The Center for Climate Integrity, Resilient Analytics, September 2021, Available Online: https://coolingcrisis.org/uploads/media/HotterDaysHigherCosts-CCI-September2021.pdf

7 "Ohio," Hotter Days, Higher Costs: The Cooling Crisis in America's Classrooms, Center for Climate Integrity, Available online: https://www.coolingcrisis.org/uploads/media/CCI-StateReport-Ohio.pdf

8 Mosby, Chris, "Extreme Heat Closes Schools Across Northeast Ohio," Patch, September 4, 2018, Available Online: https://patch.com/ohio/clevelandheights/extreme-heat-closes-schools-across-northeast-ohio

9 Ostroff, Jamie, "Air conditioning in Columbus City Schools," NBC4, August 13, 2021, Available Online: https://www.nbc4i.com/news/investigates/air-conditioning-in-columbus-city-schools

10 "Our District," Columbus City Schools, 2021, Available Online: https://www.ccsoh.us/domain/154

11 "Typology of Ohio School Districts," Ohio Department of Education, June 20, 2019, Available Online: https://education.ohio.gov/Topics/Data/Report-Card-Resources/Report-Card-Data-Forms-and-Information/Typology-of-Ohio-School-Districts

across all urban districts with very high student poverty in Ohio, then about 40 school buildings in urban districts across the state do not have air conditioning.[12]

Installing new air conditioning systems is expensive. Columbus City Schools Capital Improvements Director Alex Trevino estimates that retrofitting their school buildings with air conditioning units will cost about $1 million to $5 million per building.[13]

Methodology

Data on the availability of air conditioning in schools and municipal buildings is scarce. School air conditioning data is a problem that has prompted state legislative leaders to propose legislation in recent years to require the Department of Education to report the cost of installing air conditioning in old schools.[14]

Due to lack of available data, we use air conditioning coverage at Columbus City Schools as a proxy for other urban, very high poverty school districts in Ohio in order to estimate how many schools lack air conditioning. The districts included in this analysis were limited to urban, very high poverty districts in order to choose districts most similar to Columbus City Schools in resources and thus most likely to have similar air conditioning coverage.

We multiply the total number of buildings in each designated urban, high poverty district by 11 percent (12/112), the low-end estimate for the proportion of buildings in Columbus City Schools without air conditioning, to estimate the number of buildings without air conditioning in each district.[15] Cost estimates for air conditioning installation were reported by capital improvement officials at the City of Columbus. We then multiply the total estimated number of buildings without air conditioning by these cost estimates — $1 million on the low end and $5 million on the high end — to estimate the cost of installation of new air conditioning units in urban, very high student-poverty districts across Ohio under the National Oceanic and Atmospheric Administration (NOAA) RCP 4.5 climate scenario. We assume installation costs will be spread over 30 years using capital financing. We do not include interest payments in this calculation, so this is a conservative estimate of total capital financing costs.

Results

Air conditioning installation costs were estimated for urban, high poverty school districts in Ohio, which include Akron, Cincinnati, Cleveland, Columbus, Dayton, and Toledo. Table 2 shows the estimated upfront cost to install new air conditioning in urban, very high poverty districts, assuming those districts lack air conditioning at the same rates as Columbus City Schools. Assuming these are paid over a 30-year window like many capital investments and that installation will begin on or before 2050, **the annual cost by midcentury would be $1.4 to $6.8 million per year.**

12 "Ohio Public School Students," Thomas B Fordham Institute, Available Online: https://www.ohiobythenumbers.com

13 Ostroff, Jamie, "Air conditioning in Columbus City Schools."

14 "Lawmaker wants AC estimates as heat closes Ohio schools," Associated Press, September 5, 2018, Available Online: https://www.cincinnati.com/story/news/2018/09/05/ohio-schools-close-heat-lawmaker-wants-ac-estimates/1199807002/

15 Ostroff, Jamie, "Air conditioning in Columbus City Schools."

Under the RCP 4.5 climate scenario, all 88 Ohio counties are likely to experience 32 days above 80 degrees Fahrenheit by 2025.[16] Much of this cost will fall on already-struggling school district budgets.

Table 2. Estimated total costs for new air conditioning system installation needed in urban, very high poverty districts by midcentury

District	Low-End Estimate	High-End Estimate
Akron	$4.9 million	$25 million
Cincinnati	$7.1 million	$35 million
Cleveland	$7.3 million	$36 million
Columbus	$12 million	$60 million
Dayton	$3 million	$15 million
Toledo	$6.2 million	$31 million
All Urban Very High Poverty Districts in Ohio	**$41 million**	**$200 million**

Additional Considerations

Statewide costs for air conditioning installation are likely much higher, because installation in small town, rural, suburban, high poverty, and low poverty districts are excluded from this analysis. Estimates may also change if better data become available. While installation will require a single upfront investment from school districts, municipal governments and school boards should also consider additional future costs incurred by energy use, operation, and maintenance of these units.

Increased Electricity Costs

Once installed, air conditioning systems require recurring costs to operate and maintain. Hotter days and longer summers mean that new and existing units will be used on a more consistent basis. **In addition to creating more cooling capacity, Ohio municipalities must also consider higher electricity costs associated with increased air conditioning usage for all publicly owned and operated buildings.**

16 LeRoy, Sverre et al, "Hotter Days, Higher Costs: The Cooling Crisis in America's Classrooms," The Center for Climate Integrity, Resilient Analytics, September 2021, Available Online: https://coolingcrisis.org/uploads/media/HotterDaysHigherCosts-CCI-September2021.pdf

For example, according to the Center for Climate Integrity and Resilient Analytics's 2021 analysis, Ohio schools will have to spend an additional $56 million annually to operate and maintain new air conditioning systems, once installed.[17] In addition to schools, other public buildings will also be running their air conditioning systems more regularly.

Methodology

We use a Monte Carlo simulation method to estimate electrical costs related to increased demand for cooling that Ohio municipalities are expected to experience by midcentury. We simulated 10,000 possible utility spending outcomes based on a range of inputs. These inputs include the cost elasticity of temperature (in other words, how utility spending changes in response to temperature change), the percentage of utility costs spent on cooling, total utility spending by local governments in Ohio, and the projected increase in temperature through midcentury under the RCP 4.5 climate scenario. The ranges of likely values for each variable are listed in Appendix D.

We use publicly reported budgets to estimate total utility costs for Marion, Toledo, Lima, Marietta, and Youngstown.[18,19] While the budgets of Marion and Toledo include line items for utility spending, the budgets of Lima, Marietta, and Youngstown and statewide local government data do not. In order to estimate their utility costs, this analysis assumes that utility spending in these three cities is comparable to Marion as a percentage of the total budget. The annual budgets of Lima, Marietta, Youngstown, and statewide are 78 percent larger,[20] 73 percent smaller,[21] 200 percent larger,[22] and 110,000 percent larger[23] than Marion, respectively. We report "low-end increase" as the 5th percentile of all simulated increases and "high-end increase" as the 95th percentile of all simulated increases.

Results

Future utility costs related to increased air conditioning usage in public buildings were estimated for five municipalities in Ohio: Marion, Lima, Toledo, Marietta, and Youngstown.

Toledo will incur the highest increase in spending with additional cooling costs estimated between **$44,000 and $670,000 per year** by midcentury. Cumulatively, these cities are facing between **$75,000 and $1.1 million per year** in additional utility costs in order to cool public buildings. **Statewide, Ohio can expect increased cooling costs to run from a total of $5.4 million to $78 million per year.**

17 LeRoy, Sverre et al, "Hotter Days, Higher Costs."

18 "RESOLUTION APPROVING AND ADOPTING THE BUDGET OF THE CITY OF MARION, OHIO FOR THE YEAR 2019, AND DECLARING AN EMERGENCY," City of Marion, Available Online: https://www.marionohio.us/sites/default/files/files/FINANCE%20TAX%20BUDGET.pdf

19 "2021 Approved Annual Operating Budget: Detail Schedules," City of Toledo, Available Online: https://cdn.toledo.oh.gov/uploads/documents/Finance/2021-Approved-Annual-Operating-Budget.pdf

20 "2021 Legal Levels per Charter," City of Lima, Ohio, January 22, 2021, Available Online: https://www.cityhall.lima.oh.us/ArchiveCenter/ViewFile/Item/164

21 Newbanks, Michele, "Marietta City Council begins budget hearings," The Marietta Times, November 11, 2021, Available Online: https://www.mariettatimes.com/news/2021/11/marietta-city-council-begins-budget-hearings/

22 Skolnick, David, "Youngstown council approves budget," The Vindicator, March 30, 2021, Available Online: https://www.vindy.com/news/local-news/2021/03/youngstown-council-approves-budget/

23 "2019 Annual Survey of State & local Government Finances," U.S. Census Bureau, October 8, 2021, Available Online: https://www.census.gov/data/datasets/2019/econ/local/public-use-datasets.html

Table 3. Estimated annual increase in utility spending by cities in Ohio by 2050, due to additional air conditioning usage in public buildings

City	Current Estimated Annual Utility Budget	Low-End Increase	High-End Increase
Marion	$940,000	$5,000	$71,000
Lima	$1.7 million	$8,000	$130,000
Toledo	$8.8 million	$44,000	$670,000
Marietta	$220,000	$1,000	$16,000
Youngstown	$2.8 million	$14,000	$210,000
Ohio	**$1 billion**	**$5.4 million**	**$79 million**

Constructing Cool Roofs

Cool roofs reduce the need for air conditioning, and in some cases serve as an alternative to air conditioning systems. They are designed to reduce the temperature within a building by installing material that reflects more sunlight, decreasing the need to install or run expensive air conditioning systems.[24] The City of Cincinnati has already started to encourage the use of cool roofs with the 2018 Green Cincinnati Plan recommending deployment of cool roofs on new construction in the city.[25]

24 "Cool Roofs," Energy Saver, Available Online: https://www.energy.gov/energysaver/cool-roofs

25 "Heat Island Community Actions Database," United States Environmental Protection Agency, January 8, 2022, Available Online: https://www.epa.gov/heatislands/heat-island-community-actions-database

Methodology

Recent Census Bureau estimates show that average public sector construction spending in the United States between October 2021 and February 2022 has hovered around $350 billion per month.[26] If national construction spending stays constant over this period, annual spending for 2022 should be roughly $4.3 trillion. If Ohio's construction spending is proportionate to that of the country as a whole, then it should be spending about $150 billion per year on public sector construction.[27]

2021 estimates put residential roofing costs between $4 and $6.50 per square foot and total residential construction costs at about $100 per square foot, suggesting roofing costs about 4 to 6 percent of total construction.[28,29] Using Environmental Protection Agency (EPA) data, we estimate cool roofing coating may cost up to $0.32 per square foot in 2022 dollars.[30] We use this figure to conservatively estimate the annual cost of constructing cool roofing for one percent of new construction statewide and in select Ohio cities.

Results

Ohio is unlikely to require all new construction to have cool roofing. But if new roofing accounts for just one percent of new public sector construction by midcentury, **the additional cost to install cool roofing statewide would be roughly $4.6 million per year in 2021 dollars.** Cool roof construction costs were also estimated for the following Ohio cities: Lima, Marietta, Marion, Toledo, and Youngstown (Table 4).

26 "Monthly Construction Spending, September 2021," United States Census Bureau, November 1, 2021, Available Online: https://www.census.gov/construction/c30/pdf/release.pdf

27 The actual number may be lower than this since Ohio is growing slower than the country as a whole and may have less construction than its current population would suggest.

28 "Roof Replacement Cost 2021: New Roof Installation Prices per Sq.Ft.," Roofing Calculator, October 14, 2021, Available Online: https://www.roofingcalc.com/roof-replacement-cost/

29 "How Much Does It Cost to Build a House in Ohio," Clever Real Estate, October 21, 2021, Available Online: https://listwithclever.com/real-estate-blog/how-much-does-it-cost-to-build-a-house-in-ohio/

30 "Using Cool Roofs to Reduce Heat Islands," United States Environmental Protection Agency, July 15, 2021, Available Online: https://www.epa.gov/heatislands/using-cool-roofs-reduce-heat-islands

Table 4. Estimated costs of cool roofing per year per city if 1 percent of new construction includes cool roofing by 2050

City	Potential annual cost of cool roofing construction
Lima	$14,000
Marietta	$5,200
Marion	$14,000
Toledo	$110,000
Youngstown	$26,000
Ohio	**$4.6 million**

Cooling Centers

Cooling centers are air-conditioned public buildings designated as safe locations during times of extreme heat.[31] Cooling centers may be government buildings like libraries or schools, public-oriented buildings like community centers, religious centers, or recreation centers, or even private businesses like coffee shops, malls, and movie theaters. **Cooling centers are used as part of a larger heat health warning system, designed to reduce deaths from heat exposure.** They are considered a best practice for reducing heat-related deaths.[32,33]

A literature review conducted by the Centers for Disease Control and Prevention (CDC) found that even a few hours spent in a cool environment reduces the risk of vulnerable populations to heat exposure-related illness.[34] Socially vulnerable populations such as the elderly or unemployed are more likely to utilize the services provided by cooling centers.

As temperatures in Ohio continue to rise as a result of climate change, Ohio cities will incur additional costs to support and expand new and existing cooling center capacity during times of extreme heat. Such costs could include staff capacity, supplies such as bottled water, utilities, and implementation of systems for tracking high-risk individuals.[35]

31 Widerynski, Stasia et al, "The Use of Cooling Centers to Prevent Heat-Related Illness: Summary of Evidence and Strategies for Implementation," Climate and Health Technical Report Series, Climate and Health Program, Centers for Disease Control and Prevention, Available Online: https://www.cdc.gov/climateandhealth/docs/UseOfCoolingCenters.pdf

32 "Heat Alert and Response Systems to Protect Health: Best Practices Guidebook," Government of Canada, Available Online: https://www.canada.ca/en/health-canada/services/environmental-workplace-health/reports-publications/climate-change-health/heat-alert-response-systems-protect-health-best-practices-guidebook.html#a351

33 Widerynski, Stasia et al, "The Use of Cooling Centers to Prevent Heat-Related Illness."

34 Widerynski, Stasia et al, "The Use of Cooling Centers to Prevent Heat-Related Illness."

35 Berisha, Vjollca et al, "Assessing adaptation strategies for extreme heat: a public health evaluation of cooling centers in Maricopa County, Arizona." Weather, climate, and society 9, no. 1 (2017): 71-80.

Methodology

To estimate the annual municipal cost of expanding cooling center capacity due to climate-related temperature increase, we first estimate the total number of cooling centers that Ohio cities currently operate. We used a 2015 study of cooling centers in Pittsburgh as a starting point. In this study, researchers from Carnegie Mellon University found the city was operating 19 cooling centers at the time of publication.[36]

We estimate the current number of cooling centers in each Ohio city by using historic heat-related death rates as a proxy for heat risk and population, assuming that cities with high historic heat-related deaths operate more cooling centers than those with less.[37] This was done by taking the ratio of historic heat deaths in each Ohio city from 1985 to 2006 to heat deaths in Pittsburgh over the same period and multiplying it by 19, the number of cooling centers in Pittsburgh.

To adjust for differences in geographic size between Pittsburgh and Ohio cities, we multiply the estimated number of current cooling centers adjusted for historic heat deaths by the ratio of square miles of each Ohio city to the square miles of Pittsburgh, assuming cities with a larger area footprint will require more cooling centers to provide the same amount of cooling services.[38]

The Emergency Management Department of Los Angeles, estimates that a cooling center costs roughly $2,000 a day to operate in their city.[39] This comes very close to an estimate by Sacramento County that a cooling center costs $1,900 to operate for 12 hours, covering the hottest part of a day.[40] We use this assessment as a starting place in order to estimate the cost of operating cooling centers in select Ohio cities. Using the Bureau of Labor Statistics inflation calculator, the Los Angeles City Emergency Management Department estimate is adjusted to summer 2021 dollars.[41] Next, we multiply the adjusted Los Angeles City Emergency Management cost estimate by the ratio of local salaries for front desk receptionists in Ohio to the same salary in Los Angeles to estimate the per-day cost for running a local cooling center in a given Ohio municipality.[42]

Additional annual cost to expand days of service at existing cooling centers

To estimate the additional cost for running cooling centers in a given Ohio city due to change in climate, we multiply the per-day cost for running a cooling center by the additional number of days a city will have a heat index over 90 degrees Fahrenheit by

36 Bradford, Kathryn et al, "A heat vulnerability index and adaptation solutions for Pittsburgh, Pennsylvania." Environmental science & technology 49, no. 19 (2015): 11303-11311.

37 Gasparrini, Antonio et al, "Mortality risk attributable to high and low ambient temperature: a multicountry observational study." The lancet 386, no. 9991 (2015): 369-375.

38 "QuickFacts," United States Census Bureau, Available Online: https://www.census.gov/quickfacts/fact/table/akroncityohio,cincinnaticityohio,clevelandcityohio,columbuscityohio,daytoncityohio,cantoncityohio/PST045221

39 Reyes, Emily Alpert, "L.A. suffered deadly heat, yet chairs sat empty at its cooling centers," Los Angeles Times, September 19, 2020, Available Online: https://www.latimes.com/california/story/2020-09-19/la-deadly-heat-empty-cooling-centers

40 Nichols, Chris, "Despite The Heat, Few Take Advantage Of Sacramento Cooling Centers," CapRadio, California State University, June 18, 2021, Available Online: https://www.capradio.org/articles/2021/06/18/despite-the-heat-few-take-advantage-of-sacramento-cooling-centers

41 "CPI Inflation Calculator," Bureau of Labor Statistics, Available Online: https://www.bls.gov/data/inflation_calculator.htm

42 "Front Desk Receptionist Salaries," Glassdoor.com, 2022, Available Online: https://www.glassdoor.com/Salaries/ohio-front-desk-receptionist-salary-SRCH_IL.0,4_IS2235_KO5,28.htm

midcentury under the RCP 4.5 climate scenario.[43] This reflects how many additional days of service will be needed in order to maintain current quality of services for residents, which is also in line with a recent change in cooling center policy in Spokane, Washington due to the rising numbers of high-heat days.[44]

Total cost to expand cooling centers to achieve maximum city coverage
The Carnegie Mellon study found that Pittsburgh would need 127 cooling centers to provide maximum coverage to Pittsburgh residents, about a 600 percent increase in cooling center coverage. We estimate the number of new cooling centers needed to hit maximum coverage in a given Ohio city by multiplying the current estimated number of cooling centers by the ratio of new cooling centers needed in Pittsburgh to current cooling centers (127/19). We then multiply the number of centers needed by the projected number of 90-degree days at midcentury and per-day operation costs to estimate the cost of maximum coverage. We add the cost of new cooling centers to the cost of expanding operation of current cooling centers to estimate a total cost of maximum coverage of cooling centers in a given city.

We used historical data from the following cities to estimate the statewide increase in annual cost for operating cooling centers with the rising number of 90-degree days: Akron, Canton, Cincinnati, Cleveland, Columbus, Dayton, Hamilton, Toledo, and Youngstown. Because these cities represent only a portion of the state, this estimate understates the true statewide costs.

Results

Across Ohio, **municipalities will need to expand the number of days that cooling centers are open by an average of 30 days per year due to rising temperature and more frequent days of extreme heat in order to keep services at current level.** We estimate this will cumulatively cost Ohio municipalities an additional **$52 million per year** in additional operating expenses. Local governments will also need to expand the number of existing cooling centers to provide maximum coverage to residents. We estimate that **the state of Ohio would need to operate an additional 5,900 cooling centers by midcentury to provide this coverage, which would cost Ohio municipalities an additional $590 million per year to operate.**

43 Dahl et al, "Killer Heat in the United States: Climate Choices and the Future of Dangerously Hot Days," Union of Concerned Scientists, July 2019, Available Online: https://www.ucsusa.org/resources/killer-heat-united-states-0#ucs-report-downloads

44 Shanks, Adam, "Spokane cooling centers open more regularly, carry costs," The Spokesman-Review, August 16, 2021, Available Online: https://www.spokesman.com/stories/2021/aug/16/spokane-cooling-centers-open-more-regularly-carry-/

Table 5. Estimated annual costs of operating cooling centers expected by 2050

City	Additional days of operation	Annual cost for additional days of cooling center operation	New centers needed for full coverage	Full coverage total annual cost
Akron	28	$390,000	48	$3.9 million
Canton	29	$120,000	14	$1.2 million
Dayton	37	$480,000	44	$5.5 million
Toledo	31	$480,000	54	$5.4 million
Youngstown	29	$180,000	21	$1.8 million
Ohio	**33**	**$52 million**	**5,900**	**$590 million**

2. Road Repair

Roadways in the United States are vulnerable to a range of climate impacts. Road damage is caused not only by the wear and tear of vehicle travel, but also by weather impacts. **Frequent extreme heat events, higher temperatures, more rapid freeze/thaw cycles, and increased flooding from heavy rains can significantly affect the safety and longevity of major roadways.**

For example, a 2017 study estimated that as of 2010, pavement costs had increased by **$14 billion** in the United States due to rising temperatures.[45] The authors project these numbers will rise to **$19 billion** in 2040 under the RCP 4.5 climate scenario. These costs fall disproportionately on local governments, which are tasked by state governments with maintenance of local roadways.

45 Underwood, B. Shane et al, "Increased costs to US pavement infrastructure from future temperature rise." Nature Climate Change 7, no. 10 (2017): 704-707.

Methodology

We base road repair estimates for Ohio on results from a 2019 United States EPA study, which simulated reactive and proactive repair and rehabilitation costs needed to maintain the level of service (road quality) on roads made vulnerable by climate change. Specifically, the EPA study examined the vulnerability of current paved, unpaved, and gravel roads to future changes in temperature, precipitation, and freeze/thaw cycles in the United States as a whole.[46] Results yield annual damages of $2.7-16 billion by 2050 under the RCP 4.5 scenario.[47] We use low, expected, and high estimates from the report as a baseline, while assuming the cost to Ohio and to the selected localities will be proportional to miles of public roads in these areas, compared to miles of public roads in the United States as a whole. We estimate future annual road repair costs due to climate change for a given Ohio locality by dividing the total road mileage of a locality by the total road miles in the United States, then multiplying that ratio by the total cost of climate change-related road repairs expected nationwide by 2050.

Results

Table 6 shows estimates reflecting how future changes in temperature, precipitation and freeze-thaw cycles will affect roads in Ohio and in the following Ohio localities: Dayton, Lima, Marion, Washington County, and Youngstown. Low- and high-end repair and rehabilitation costs were estimated for the RCP 4.5 future climate scenario. **Statewide, Ohio will be facing costs of $170 million to $1 billion per year with a likely value of $410 million per year for road repair related to climate change by midcentury.**

Table 6. Estimated annual costs expected to incur by midcentury for road repair and rehabilitation associated with future changes in temperature, precipitation, and freeze–thaw cycles

Area	Low-Cost Estimate	Expected Cost	High-Cost Estimate
Dayton	$1.1 million	$2.6 million	$6.5 million
Lima	$97,000	$230,000	$570,000
Marion	$86,000	$210,000	$510,000
Washington County	$220,000	$530,000	$1.3 million
Youngstown	$710,000	$1.7 million	$4.2 million
Ohio	**$170 million**	**$410 million**	**$1 billion**

46 Martinich, Jeremy, and Allison Crimmins, "Climate damages and adaptation potential across diverse sectors of the United States." Nature climate change 9, no. 5 (2019): 397-404.

47 Martinich and Crimmins, "Climate damages and adaptation potential across diverse sectors of the United States." Supplementary Table 5: Projected annual economic impacts of climate change across sectors at the national scale, Available Online: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6483104/#SD1

Additional Considerations

In 2021, Ohio's roads received a "D" rating from the American Society for Civil Engineers.[48] The scorecard also notes that 17 percent of Ohio's roads are in poor condition and the average Ohio motorist pays an extra $500 per-year in costs due to driving on damaged roads. According to the report, local governments projected needing more than $3.2 billion annually by 2030 in order to catch up on deferred maintenance projects and begin to address future maintenance needs.[49] Because climate change is expected to exacerbate these existing problems, this analysis likely underestimates the total cost to repair Ohio's roads to best-practice engineering standards.

48 "Ohio 2021 Report," Report Card for Ohio's Infrastructure, American Society for Civil Engineers, Available Online: https://infrastructurereportcard.org/state-item/ohio/

49 "Gross Domestic Product: All Industry Total in Ohio," FRED, Federal Reserve Bank of St. Louis, Available Online: https://fred.stlouisfed.org/series/OHNGSP

3. Protecting Drinking Water

Harmful algal blooms, or blooms that produce toxic cyanobacteria, have increased dramatically over the past decade, particularly in the eastern United States.[50] These blooms have disrupted drinking water supplies in Ohio and elsewhere and have cost municipalities across the country millions to monitor, treat, and manage.[51]

According to the United States EPA, warmer water temperatures and increased runoff of phosphate fertilizers from more frequent heavy rains due to climate change lead to the conditions that can produce more harmful, widespread, and frequent algae blooms.[52] **With climate change expected to make harmful algae blooms more likely in the future, the nation's drinking water supply is increasingly vulnerable to contamination.**[53] The EPA recommends biological, physical, and chemical measures for prevention of harmful algae blooms.[54]

50 Herman, Rob, "Toxic Algae Blooms Are on the Rise," Scientific American, September 7, 2016, Available Online: https://blogs.scientificamerican.com/guest-blog/toxic-algae-blooms-are-on-the-rise/

51 Schechinger, Anne, "The High Cost of Algae Blooms in U.S. Waters: More Than $1 Billion in 10 Years," Environmental Working Group, August 26, 2020, Available Online: https://www.ewg.org/research/high-cost-of-algae-blooms/

52 "Climate Change and Harmful Algal Blooms," United States Environmental Protection Agency, Available Online: https://www.epa.gov/nutrientpollution/climate-change-and-harmful-algal-blooms

53 "Climate Change and Harmful Algal Blooms," United States Environmental Protection Agency.

54 "Preventative Measures for Cyanobacterial HABs in Surface Water," United States Environmental Protection Agency, Available Online: https://www.epa.gov/cyanohabs/preventative-measures-cyanobacterial-habs-surface-water

Ohio has a history of dealing with algae blooms, especially communities along the coast of Lake Erie. University of Toledo Economist Kevin Egan has found algae blooms cost the state of Ohio millions of dollars a year in lost tourism activity since tourism in the state is concentrated in its northern lakefront counties.[55]

In October 2010, the City of Celina, Ohio, estimated it had spent $13 million to install treatment controls and set up toxic algae testing due to widespread algae blooms in Grand Lake St. Marys, the largest inland lake in Ohio and drinking water supply for the City of Celina and Village of St. Marys.[56] A 2021 analysis by the Environmental Working Group found that Ohio spent nearly $820 million on preventing and treating algae blooms in the past 10 years, nearly 11 times more than the next-closest state.[57] As blooms get worse with climate change, this number could increase.

Methodology

The statewide annual cost of prevention and treatment of algae blooms in the Environmental Working Group analysis was used as a baseline to estimate municipal costs for algae blooms in Ohio for the RCP 4.5 climate scenario. Previous cost estimates for municipalities were scaled up proportionally based on the relative population in each city and the number of people receiving their drinking water from Lake Erie. These numbers were then multiplied by the projected increase in days of algal outbreak divided by a baseline of past algal activities projected by a team of researchers from the United States EPA, the Massachusetts Institute of Technology, Oak Ridge National Laboratory, and other prominent research institutions.[58]

Best and worst-case climate cost scenarios were estimated using climate models projecting both low and high temperature changes under the RCP 4.5 scenario. The best-case scenario model projects that algal growth will increase initially, but will taper and wane in higher temperatures. The worst-case scenario model projects that algal growth will steadily become more intense with higher temperatures. We use the results of the algal growth models presented in this study to estimate the projected increase in the number of days of algal outbreak in Ohio.[59]

55 Egan, Kevin, Invited Presentation, Ohio Association of Economists and Political Scientists Annual Conference, Tiffin, Ohio, 2017.

56 "A compilation of cost data associated with the impacts and control of nutrient pollution." United States Environmental Protection Agency, Reports and Assessments 3 (2015): 1-25.

57 Schechinger, Anne, "The High Cost of Algae Blooms in U.S. Waters: More Than $1 Billion in 10 Years."

58 Chapra, Steven C et al, "Climate change impacts on harmful algal blooms in US freshwaters: a screening-level assessment." Environmental Science & Technology 51, no. 16 (2017): 8933-8943.

59 Chapra, Steven C. et al, "Climate change impacts on harmful algal blooms in US freshwaters." "What Climate Change Means for Ohio," United States Environmental Protection Agency, August 2016, Available Online: https://19january2017snapshot.epa.gov/sites/production/files/2016-09/documents/climate-change-oh.pdf

Results

The statewide additional cost to protect water supplies from toxic algae blooms in Lake Erie is estimated to reach $580 million to $2.2 billion per year by midcentury. Municipal costs are listed in Table 7. The estimated cumulative cost for water treatment in the four largest Ohio cities that abut Lake Erie — Cleveland, Lorain, Sandusky, and Toledo — is **$37 million to $140 million per year.**

Table 7. Estimated additional annual costs of protecting water supplies from hazardous algae blooms by midcentury

Area	Baseline Cost	Best-Case Additional Climate Cost	Likely Additional Climate Cost	Worst-Case Additional Climate Cost
Cleveland	$26 million	$19 million	$34 million	$71 million
Lorain	$4.4 million	$3.2 million	$5.7 million	$12 million
Sandusky	$1.7 million	$1.2 million	$2.2 million	$4.6 million
Toledo	$19 million	$13 million	$24 million	$51 million
Ohio	**$820 million**	**$580 million**	**$1 billion**	**$2.2 billion**

Additional Considerations

While temperature will likely impact algal blooms in Ohio, increased runoff from heavy precipitation will likely also increase the presence of algal blooms. This is particularly true in Ohio due to the significant amount of farmland in the state. This means that the cost estimates in this analysis may underestimate the true cost to treat algae blooms associated with climate change for Ohio municipalities if increased precipitation and runoff leads to more common algae blooms.

4. Recovery and Adaptation to Heavy Precipitation

As climate change increases the frequency and severity of storms and heavy precipitation events, Ohioans will be forced to confront increased costs for storm recovery, clean-up, and stormwater management, as well as costs to adapt critical infrastructure to high incidence flooding events.

According to the United States EPA, average annual precipitation in the Midwest has increased by 5 to 10 percent over the last 50 years.[60]

Particularly, the frequency and intensity of heavy precipitation events are increasing. According to the Great Lakes Integrated Sciences and Assessments team (GLISA) at the University of Michigan, total annual precipitation has grown by 14 percent in the Great Lakes region since 1951 and the amount of rain falling in the heaviest one percent of storms in the region has grown by 35 percent.[61]

The team also projects **average annual precipitation will grow by two to six inches by the end of the 21st century** and that higher levels of water vapor in the air combined with rising temperatures will create conditions for more intense storms in the future.

GLISA also analyzed the City of Dayton, finding that the number of extreme precipitation events (heaviest one percent of storms) increased by 85 percent from 1981 to 2010 and total volume of rainfall during these events increased by 71 percent. They project that Dayton is likely to see 1.6 more days per year of heavy precipitation by midcentury and could see as many as 3.6 more days of heavy precipitation under worst-case scenarios.

Storm Recovery and Clean-up

Methodology

The National Centers for Environmental Information (NCEI) at the National Oceanic and Atmospheric Association (NOAA) track and evaluate climate events in the United States that have great economic and societal impact. Recent examples include severe winds across the North Central states, including parts of Ohio, in August 2021 that killed two people and caused $1.3 billion in damages, and June 2021 hail storms in the Ohio Valley that caused $1.8 billion in property damage.[62] We use the cost of historical disaster events between 1980 and 2021 as reported by NCEI and NOAA, as a baseline for estimating future annual costs from flooding, drought, hurricane winds, and severe storms.[63]

Flooding

We used the First Street Foundation Flood Factor estimates to project the extent of flooding expected by midcentury under the RCP 4.5 scenario. Flood Factor estimates the number of properties in the state of Ohio at one percent risk of flooding will increase from 510,000 in 2022 to 540,000 by 2052.[64] Assuming the value of properties entering this risk category for flooding is proportional to the value of properties previously in the flood risk category, we multiply the growth rate of properties at risk of flooding by the 1980-2021 historic annual spending on flooding to arrive at an estimate for the cost of flooding in a given year. We then multiply this estimate for rate of growth for properties at risk by

60 "What Climate Change Means for Ohio," United States Environmental Protection Agency, August 2016, Available Online: https://19january2017snapshot.epa.gov/sites/production/files/2016-09/documents/climate-change-oh.pdf

61 "Climate Changes in the Great Lakes region and Dayton, Ohio," Great Lakes Integrated Sciences and Assessments: A NOAA RISA Team, University of Michigan, Available Online: https://glisa.umich.edu/wp-content/uploads/2021/03/Dayton-Climate-Summary.pdf

62 NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2022). Available Online: https://www.ncei.noaa.gov/access/billions/

63 NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters.

64 "Flood risk overview for Ohio," Flood Factor, First Street Foundation, Available Online: https://floodfactor.com/state/ohio/39_fsid#historic_flooding

the low- and high-end historical cost estimates to arrive at our final estimates for cost of flooding to Ohio.

Drought

A study by United States Department of Agriculture (USDA) researchers estimated that drought severity would increase by 26 percent in Ohio by midcentury under the RCP 4.5.[65] To estimate the midcentury cost of drought, we multiply 1980-2021 historic annual spending on drought in Ohio by USDA's projected increase in Midwest drought severity.

Hurricane winds

TransRe, a leading international reinsurer, projects that the frequency of major hurricanes will increase by 20 percent in the United States by midcentury under the RCP 4.5 climate scenario.[66] To estimate the annual cost of hurricane-related wind damage that Ohio cities can expect to incur by midcentury, we multiply 1980-2021 historic annual spending on hurricane wind damage in Ohio by TransRe's projected increase in major hurricanes.

Severe Storms

A study from Climate Central uses the RCP 4.5 climate scenario to project future storm frequency in the United States.[67] To estimate the annual cost of severe storm events that Ohio cities will incur by midcentury, we multiply 1980-2021 historic annual spending in Ohio on severe storm events by 0.75 percent, Climate Central's estimated average percentage increase in storm numbers for 10 Ohio cities.

Results

Statewide costs associated with recovery and clean up from increased frequency and severity of extreme weather events are expected to reach $35 million to $78 million per year by midcentury. Below are the midcentury estimates for annual costs associated with increased frequency of four distinct extreme weather events. The range of estimates is mainly driven by the range of historical estimates of costs associated with extreme weather events.

65 Peters, Matthew P., and Louis R. Iverson. "Projected drought for the conterminous United States in the 21st century." (2019).

66 "U.S. Hurricane Risk Volatility Case Study: An Alternative to Current Climate Change Scenarios," TransRe ESG, December 2021, Available Online: https://www.transre.com/wp-content/uploads/2021/12/TransRe_US-Hurricane-Risk-Case-Study-FINAL.pdf

67 "Climate Pile-Up: Global Warming's Compounding Dangers," Research Brief, Climate Central, February 20th, 2019.

Table 8. Estimated statewide annual costs by 2050 associated with an increase in severe weather events

Event	Low-End Estimate	High-End Estimate
Flooding	$1.3 million	$3 million
Drought	$21 million	$44 million
Hurricane Winds	$11 million	$28 million
Severe Storm	$1.5 million	$3.4 million
Total	**$35 million**	**$78 million**

Protecting Power Lines

With increased storm severity and frequency, Ohio communities will face increased maintenance costs to protect power lines from damaged trees.

Methodology

FirstEnergy has recently been negotiating with public utilities commissions to increase rates to pay for vegetation management around power lines.[68] These rate increases come out to about $4 monthly per customer in 2021 dollars, or $48 a year. We multiply this number by the number of customers of public power statewide and in select public power districts to estimate the annual cost of enhanced tree pruning programs in these jurisdictions. We then multiply this number by the projected increase in midcentury extreme storms in a study from Climate Central, assuming pruning costs will increase proportionally with storm frequency.[69]

68 Shelor, Jeremiah, "FirstEnergy seeking $38M increase for tree-trimming program," The Exponent Telegram, September 1, 2015, Available Online: https://www.wvnews.com/theet/news/local/firstenergy-seeking-38m-increase-for-tree-trimming-program/article_b76c4794-9727-59b3-9c2e-a37619f127f0.html

69 "Climate Pile-Up: Global Warming's Compounding Dangers," Research Brief, Climate Central.

Results

Statewide municipal power costs for pruning of trees are estimated to increase by about $140,000 per year by midcentury to adapt to increases in storms, and up to $18 million per year if municipal utilities who have not chosen to adopt full enhanced pruning programs begin the programs in response to the threat of climate change.

Table 9 shows estimated increased annual costs of pruning trees for select municipal power companies by comparing their relative customer base to statewide customer base. It also includes cost estimates for implementing an enhanced pruning cost program, should local officials see that as an appropriate response to the increased risk of storms resulting from climate change.

Table 9. Estimated annual costs incurred by midcentury for pruning for select municipal power distributors

Distributor	Additional Cost	Full Enhanced Pruning Cost
Cleveland	$29,000	$3.9 million
Cuyahoga Falls	$8,700	$1.2 million
Oberlin	$1,100	$150,000
Piqua	$3,900	$520,000
Wadsworth	$4,700	$630,000
Ohio	**$140,00**	**$18 million**

Stormwater Management

With climate change causing heavier and more frequent precipitation, Ohio municipalities will need to make upgrades to their stormwater management systems to provide the same quality of service as in the past. This could mean adding extra culverts or installing detention or retention basins, rain gardens, infiltration trenches, and other stormwater management techniques to address more frequent and severe rainfall.

The United States EPA lists retention basins and other strategies as effective strategies for dealing with changes in rainwater frequency.[70] However, increased frequency and intensity of rain caused by climate change is impacting the design of retention basins all across the world.[71] In particular, a recent study found that the biggest threat for flooding comes not from the total rain during a storm, but the total rain at the heaviest point during the storm.[72] This is because detention and retention basins can adequately drain during the course of a storm but are most threatened for overflow and failure when storming is worst. More heavy rains or more intense weather events could thus require not only installation of new basins or spillways, but a combination of different stormwater management technologies.

Three other strategies for managing stormwater runoff are rain gardens, infiltration trenches, and sand filters. A rain garden is a depressed area that collects rainwater and allows it to soak into the ground.[73] An infiltration trench is a ditch full of permeable soil that allows rainwater to quickly seep into the ground.[74] A sand filter captures water and then filters out larger particles and smaller impurities by running them through sand.[75]

Methodology

In order to estimate the cost of stormwater management, we use the Community-enabled Lifecycle Analysis of Stormwater Infrastructure Costs (CLASIC) tool designed by the Colorado State University One Water Solution Institute. To estimate the annual costs of stormwater projects for local governments in Ohio, we modeled stormwater projects in Lima, Marietta, Marion, Toledo, and Youngstown, setting city boundaries as study areas. We use an estimate of four percent increased precipitation per year by midcentury as our forecasted climate scenario. This was calculated by taking the median estimate from twenty different climate models, which project average annual precipitation increase for the RCP 4.5 climate scenario.[76]

70 Clar, Michael L., "Stormwater Best Management Practice Design Guide - Volume 3: Basin Best Management Practices," National Risk Management Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, OH 45268, September 2004, Available Online: https://cfpub.epa.gov/si/si_public_record_Report.cfm?Lab=NRMRL&dirEntryID=99760

71 Sanches Fernandes, Luis F. et al, "Influence of climate change on the design of retention basins in northeastern Portugal." Water 10, no. 6 (2018): 743.

72 Elshorbagy, Amin, Kelsea Lindenas, and Hossein Azinfar. "Risk-based quantification of the impact of climate change on storm water infrastructure." Water Science 32, no. 1 (2018): 102-114.

73 "Soak Up the Rain: Rain Gardens," United States Environmental Protection Agency, Available Online: https://www.epa.gov/soakuptherain/soak-rain-rain-gardens

74 "Infiltration Trenches," Stormwater Management, Available Online: https://www.esf.edu/ere/endreny/GICalculator/InfiltrationIntro.html

75 "Sand Filters Basins," Stormwater Management, Available online: https://www.esf.edu/ere/endreny/GICalculator/SandFilterIntro.html

76 Joyce, Linda A and David Coulson, "Climate Scenarios and Projections: A Technical Document Supporting the USDA Forest Service 2020 RPA Assessment," Gen. Tech. Rep. RMRS-GTR-413, U.S. Forest Service, United States Department of Agriculture, May 2020, Available Online: https://www.fs.fed.us/rm/pubs_series/rmrs/gtr/rmrs_gtr413.pdf

We then model 10 technological options for each selected Ohio municipality and choose the least-cost technology that results in either baseline or reduced runoff volume. The 10 technological options modeled using the CLASIC tool are detention basins, rain gardens, sand filters, infiltration trenches, wet ponds, stormwater harvesting, storage vaults, permeable pavements, disconnections, and green roofs. Six months of annual mowing is assumed for projects that require them and construction costs are assumed to be spread over 30 years using capital financing. We do not include interest payments in this calculation, so this is a conservative estimate of total capital financing costs.

We conducted sensitivity analysis as well, testing scenarios with high-end estimates for precipitation increase under the RCP 4.5 scenario, and these technologies were robust enough to absorb runoff under the highest precipitation estimates among the 20 climate models considered.

To estimate statewide costs, we determine costs per municipal square mileage of cost-effective technologies in select municipalities using dollar estimates from the CLASIC model and square mileage from the Census Bureau's "QuickFacts" tool.[77] We then multiply these average per-square mile costs by the number of square miles in Ohio and then by the percentage of urban square miles in Ohio as estimated by the United States Department of Agriculture (USDA) to estimate the total cost of stormwater management to account for increased precipitation for the state's municipalities in the RCP 4.5 climate scenario.[78]

Results

Of the 10 technologies studied, three technologies — rain gardens, infiltration trenches, and sand filters — were effective at reducing runoff at a similar low cost across municipalities. The annual construction, maintenance, and rehabilitation costs expected by midcentury for each strategy in the selected Ohio municipalities are below. **The statewide cost to implement a given stormwater management technology is estimated to reach $140 million to $150 million per year by midcentury.**

These estimates assume a single technology is used to manage stormwater. Mixing and matching technologies may increase or decrease costs depending on the watershed coverage of the technology within the municipality. These numbers also assumed that construction costs capitalized over 30 years.

77 "QuickFacts: Youngstown city, Ohio; Toledo city, Ohio; Marietta city, Ohio; Lima city, Ohio; Marion city, Ohio," United States Census Bureau, Available Online: https://www.census.gov/quickfacts/fact/table/youngstowncityohio,toledocityohio,mariettacityohio,limacityohio,marioncityohio/PST045221

78 "Overview of Ohio," Natural Resources Conservation Service, United States Department of Agriculture, Available Online: https://www.nrcs.usda.gov/wps/portal/nrcs/oh/about/outreach/nrcs144p2_029664/#

Table 10. Estimated annual costs for stormwater management infrastructure for select Ohio municipalities expected by midcentury

Municipality	Rain Gardens	Infiltration Trenches	Sand Filters
Lima	$1.5 million	$1.4 million	$1.5 million
Marietta	$590,000	$570,000	$620,000
Marion	$1.3 million	$1.7 million	$1.3 million
Toledo	$10 million	$10 million	$11 million
Youngstown	$3 million	$3 million	$3.2 million
Ohio	**$140 million**	**$140 million**	**$150 million**

Elevating Roads

Climate change is expected to cause more frequent concentrated, intense storms with heavier rainfall, which will lead to increased flooding. Climate change-driven flooding can lead to traffic disruptions, construction activity delay, and weakening and washing out of soil and culverts that support roads, tunnels, and bridges.[79] Volatility of flood levels may prompt local governments to raise the height of roads and bridges to exceed the base flood elevation in order to ensure public safety in the face of these new climate-driven flooding challenges.

Many of the models that have been developed for climate adaptation lean on using base flood elevation levels to determine what the height of roads and bridges should be under different climate change scenarios. The Federal Emergency Management Agency (FEMA) sets that base flood elevation as the elevation of surface water resulting from a flood that has a one percent chance of equaling or exceeding that level in any given year.[80] Elevating roads and bridges is an expensive undertaking. The cost of materials, labor, and even shutting down roads for maintenance and upgrades falls on local governments. If traffic disruption is large enough, local economic activity could be impacted as well. Miami Beach, Florida, is currently carrying out a project to raise its road by two feet, costing the city about $2 million per block.[81]

"Base flood elevation" is the elevation of surface water resulting from a flood that has a one percent chance of equaling or exceeding that level in any given year. This is a standard used for assessment of risk for flooding of structures and infrastructure.

79 "Climate Impacts on Transportation," Environmental Protection Agency, January 19, 2017, Available Online: https://19january2017snapshot.epa.gov/climate-impacts/climate-impacts-transportation_.html

80 "Base Flood Elevation (BFE)," Federal Emergency Management Agency, March 5, 2020, Available Online: https://www.fema.gov/node/404233

81 "Elevate roads and bridges above flood level," Flood Factor, Available Online: https://help.floodfactor.com/hc/en-us/articles/360051425073-Elevate-roads-and-bridges-above-flood-level

Methodology

To estimate the cost to elevate Ohio's roads and bridges above base flood elevation, we start with the miles of roads estimated by Flood Factor to be at risk within each Ohio city selected for analysis.[82] We then multiply this by Flood Factor's projected midcentury percentage increase in the number of properties below base flood elevation under the RCP 4.5 climate scenario. We use this ratio as a proxy estimate for the percentage increase in miles of roads falling below base flood elevation.

The Pennsylvania Department of Transportation estimates interstate reconstruction costs roughly $2.6 million per lane mile, or $5.2 million if the segment mile of Interstate has two lanes.[83] We estimate a low-end cost of raising a mile of road to be $5.2 million for a two-lane road and a high-end cost of raising a mile of road to be $10.4 million. This should be considered a conservative estimate since urban construction tends to be more expensive than rural construction.[84]

To estimate the cost to raise Ohio's roads above base flood elevation, we multiply the projected number of miles that need to be raised above base flood elevation by $5.2 million per mile for a low-end estimate and $10.4 million per mile for a high-end estimate. We then divide this number by 30, assuming construction costs will be capitalized over 30 years. We do not include interest payments in this calculation, so this should be considered a low-end estimate of the cost of these road elevation projects.

To produce a statewide estimate, we take the average percentage of roads at risk of flooding in the selected Ohio cities, which is 35 percent, and divide that by the total number of miles of road in Ohio. We then follow the same methodology used above to produce low and high-end statewide cost estimates.

Results

Ohio would need to spend between an estimated $860 million and $1.7 billion per year over 30 years to raise the state's roads above base flood elevation. Table 11 shows the estimated miles of roads falling below base flood elevation as well as low- and high-end annual cost estimates for raising these roads above base flood elevation in select Ohio cities and statewide.

82 "Flood Risk Overview," Risk Factor, First Street Foundation, Available Online: https://riskfactor.com/

83 "Governor Wolf Outlines Plan to Invest Additional $2.1 Billion for Highways and Bridges Through New Road MaP Program," Pennsylvania Department of Transportation, February 28, 2017, Available Online: https://www.penndot.pa.gov/pages/all-news-details.aspx?newsid=300#:~:text=The%20department%20estimates%20that%20Interstate,of%20Interstate%20has%20two%20lanes.

84 "Frequently Asked Questions," American Road & Transportation Builders Association, 2022, Available Online: https://www.artba.org/about/faq/

Table 11. Estimated additional miles of roads below base flood elevation for select Ohio cities and the annual cost to raise them above base flood elevation

Community	Estimated Miles of Roads Falling Below Base Flood Elevation	Annual Cost - Low	Annual Cost - High
Dayton	65	$11 million	$23 million
Lima	9	$1.5 million	$3 million
Marion	6	$1.1million	$2.1 million
Washington County	13	$2.2 million	$4.4 million
Youngstown	7	$1.3 million	$2.5 million
Ohio	**5,000**	**$860 million**	**$1.7 billion**

5. Budget Analysis of the Costs of Climate Change to Local Governments

To estimate the total impact of the cost of climate change on Ohio state budgets, we first create a baseline for spending in Ohio starting with the 2019 survey of state and local government finances by the United States Census Bureau.[85] We find that local governments in Ohio spent a total of $7.1 billion on environment and housing that year. We compare this baseline spending to low- and high-end costs for each of the deep-dive spending areas to see what the increase in environment and housing spending will be in 2050.[86]

Monster Ztudio/Shutterstock.com

85 "2019 State & Local Government Finance Tables," United States Census Bureau, October 8, 2021, Available Online: https://www.census.gov/data/datasets/2019/econ/local/public-use-datasets.html

86 All values expressed in 2022 dollars.

Table 12. Total costs of climate change for major impacts on local governments expected by midcentury

Impact	Low-End Estimate	High-End Estimate
A/C Installation	$1.4 million	$6.8 million
Electrical Costs	$5.4 million	$79 million
Cool Roofing	$0	$4.6 million
Cooling Centers	$52 million	$590 million
Road Repair	$170 million	$1 billion
Drinking Water Treatment	$580 million	$2.2 billion
Storm Recovery	$35 million	$78 million
Power Lines	$140,000	$18 million
Stormwater Management	$140 million	$150 million
Elevating Roads	$858 million	$1.7 billion
Total	**$1.8 billion**	**$5.9 billion**

We estimate that the state of Ohio will need to increase municipal spending by at least $1.8 billion to $5.9 billion per year by midcentury in order to adapt to these ten challenges of a worsening climate crisis (Table 12). This change in spending would constitute an increase in spending of 26 to 82 percent over 2019 baseline spending on environment and housing. Many of the costs of climate change are expressed in 2021 dollars, which means that simple inflation may drive these costs up on their own.

The monetized amounts also represent only 10 of the 50 different impacts addressed in this report. Monetization of the other 40 impacts would add to the overall costs reflected here. This also constitutes a static analysis of the costs associated with climate change adaptation. Behavioral responses to adoption of one policy may influence the decision to adopt other policies that could increase or lower the total cost of adaptation, but we do not estimate the impact of those changes in this analysis.

Conclusion

The impacts of climate change are underway and local governments will have to find a way to finance the local impacts of this global problem. As we see increases in extreme weather events and other consequences from the climate crisis unfold in real time, municipal governments will face new costs managing local recovery and adaptation efforts. As a part of this, local leaders must 1) understand the magnitude of costs that will be necessary to reduce the threat of climate change, and 2) implement preventative policies to avoid heavier retrofit costs down the line and to protect the lives and livelihoods of their residents.

Our analysis conservatively estimates that local governments could spend up to an additional $5.9 billion per year by midcentury to address just 10 likely impacts from climate change. This represents an 82 percent increase over 2019 baseline local spending on environment and housing in the state of Ohio. We also identified another 40 impacts which are not included in this estimate.

The total increase in annual spending by municipal governments due to climate change is likely much higher than this report reflects. Local governments will likely experience a shortfall in revenue compared to necessary climate-related expenditures. These costs are likely to occur even if international carbon emission reduction goals are reached in line with the Paris Agreement.

So what can local governments do to address this problem? First, municipalities can raise local taxes to create a climate fund. Denver has implemented a similar strategy,[87] but raising taxes can be a politically challenging solution. Petitioning the federal government for climate funding is another option, but President Biden's proposed budget for 2023 invests only $18 billion in climate resilience for the entire country[88] — not enough to cover even one year of the costs estimated in this analysis if other states have climate costs of similar magnitude to Ohio's. Both of these policy options rely on taxpayers to pick up the entire tab for climate costs. Alternatively, policymakers can pursue other financing options, such as considering who is responsible for climate change in the first place and holding those entities accountable for the existing costs and ongoing damages.

A 2017 study by the Carbon Disclosure Project and the Climate Accountability Institute found that just 100 oil and gas companies are responsible for more than 70 percent of industrial greenhouse gas emissions since 1988.[89] Many of these same companies conducted early climate change research and found that burning fossil fuels would raise global temperatures,[90] which could cause "dramatic environmental effects."[91] To this day, the oil and gas lobby is actively working to obstruct much-needed action on climate change.[92]

Taxpayers are not responsible for the climate crisis that Ohio municipalities are currently facing. Instead of relying on taxpayers to bear these costs, local governments have the option to ensure that the corporate actors most responsible for causing and exacerbating climate change should be responsible for their fair share of the financial costs of adaptation and resilience.

87 "6 Innovative Ways to Fund Climate Action and Equity in US Cities," World Resources Institute, May 6, 2021, Available Online: https://www.wri.org/insights/funding-models-climate-equity-cities-us

88 "Quantifying Risks to the Federal Budget from Climate Change," The White House, April 4 2022, Available Online: https://www.whitehouse.gov/omb/briefing-room/2022/04/04/quantifying-risks-to-the-federal-budget-from-climate-change/

89 "The Carbon Majors Database: CDP Carbon Majors Report 2017," Carbon Disclosure Project and Climate Accountability Institute, July 2017, Available Online: https://cdn.cdp.net/cdp-production/cms/reports/documents/000/002/327/original/Carbon-Majors-Report-2017.pdf

90 Memo from J.F. Black to F.G. Turpin re The Greenhouse Effect, Exxon Research and Engineering Company, June 6, 1978, Available Online: https://payupclimatepolluters.org/uploads/smoking-guns/1978-Exxon-BlackMemo.pdf

91 Memo from W.L. Ferrall to R.L. Hirsch re "Controlling Atmospheric CO2," The Exxon Research and Engineering Company, October 16, 1979, Available Online: https://payupclimatepolluters.org/uploads/smoking-guns/1979-Exxon-FerrallMemo.pdf

92 "In Video, Exxon Lobbyist Describes Efforts to Undercut Climate Action," The New York Times, June 30, 2021, Available Online: https://www.nytimes.com/2021/06/30/climate/exxon-greenpeace-lobbyist-video.html

Appendix A: Potential Costs of Climate Change for Local Governments in Ohio

Climate Impact	Cost Category	Cost
Increasing Temperatures	Infrastructure	Energy efficiency retrofits in public and private buildings and housing, including costs for the design and development of energy efficiency standards.
		Increased costs for A/C installation or upgrade costs for public schools.
		Increased electrical costs required for air conditioning in public buildings
		Increased cooling costs associated with roofing solutions, such as cool or green roofing
		Increased road damage due to more frequent extreme heat events, and more rapid freeze/thaw cycle.
		Increased damage to water and sewer pipes due to more frequent freeze/thaw cycle.
	Public Health Projects	Building and managing more cooling centers, including staffing and tracking of high-risk individuals.
		Increased demand for publicly financed air conditioning targeted to low-income families and public housing.
		Controlling the increase of vector borne illness – education and physical and chemical controls for ticks and mosquitos.
		Treating victims of vector borne illness.
		Increase in asthma attacks requiring hospitalization (resulting from increased heat and ground level ozone, and the increase in airborne allergens due to lengthened growing season).
		Reducing the urban heat island by planting trees to provide shade in parking lots, school playgrounds, residential streets, and public right-of ways.
		Protecting drinking water supplies from hazardous algae blooms, caused in part by increasing water temperatures.
Extreme Precipitation and Flood Protection	Structure and Infrastructure Projects	Removing, relocating, acquiring, or demolishing structures from flood-prone areas to minimize future flood losses.
		Installing, rerouting, increasing capacity, or implementing routine cleaning plans for the storm drainage system.
		Adding extra culverts, increasing dimensions of existing culverts, or implementing routine cleaning and repairing.
		Installing detention or retention basins, relief drains, spillways, drain widening/dredging or rerouting, etc.
		Inspecting and maintaining drainage systems and flood control structures (dams, levees, ice-jam preventers, etc.).
		Inspecting bridges in order to identify and/or implement repairs or retrofits or cleaning under low bridges.
		Resurfacing roads with more permeable pavement and concrete to better handle increase rainfall.
		Elevating roads and bridges above the base flood elevation (BFE) to maintain dry access.
		Elevating structures above the base flood elevation (BFE), or relocating utilities, water heaters, etc. above BFE.
		Floodproofing inside of municipal buildings, for example by installing check valves, sump pumps, or backflow prevention devices.
		Floodproofing wastewater treatment facilities located in flood hazard areas.
		Floodproofing water treatment facilities located in flood hazard areas.

		Protecting emergency operations by upgrading or moving all emergency operations centers, police stations, and fire department facilities outside of flood-prone areas.
		Protecting critical and emergency facilities by requiring all critical facilities be built one foot above the 500-year flood elevation (to meet requirements of Executive Order 11988).
		Protecting critical and emergency facilities from floods using any other technique, for example, raising components above BFE, installing pumping systems or back-up generators for pumping, building dikes or stabilizing banks.
		Constructing floodwalls, small berms, revetments, bioengineered bank stabilization or other small structural mitigation measures.
	Natural Systems Protection	Protect and enhance natural floodplain mitigation features (such as wetlands, dunes, and vegetative buffers) to help prevent flooding in other areas.
	Local Planning and Regulations	Developing a floodplain or coastal zone management plan.
		Adopting a stormwater management or drainage plan, or completing a stormwater drainage study to address flooding/erosion related to rainwater or snowmelt.
		Adopting, applying and enforcing building codes to ensure buildings can withstand flooding.
		Obtaining easements to use privately-owned land for temporary water retention and drainage.
		Joining or improving compliance with the National Flood Insurance Program (NFIP).
		Implementing floodplain management beyond NFIP requirements, like the Association of State Floodplain Managers "No Adverse Impact" policy or FEMA NFIP Community Rating System (CRS).
		Preserving floodplains as open space using any of several land use planning tools: develop a plan that targets hazard areas for acquisition, reuse, and preservation, a land banking program, use of transfer of development rights to keep floodplains vacant, easements to prevent development, or acquiring properties in the floodplain and turning them into open space.
	Education and Awareness Programs	Increasing public outreach to encourage flood insurance purchase; educate residents in flood safety, flood mitigation, technical assistance availability, funding sources and best practices.
Erosion	Infrastructure Projects	Relocating, demolishing or acquiring at-risk buildings (or other infrastructure).
		Locating new utilities and critical facilities outside of susceptible areas.
		Implementing site and building design standards, such as constructing open foundation systems or deep foundations.
		Stabilizing susceptible slopes, stream banks, and shorelines using grading techniques, planting vegetation, terracing hillsides, installing boulders, riprap or geotextile fabric, or bioengineering bank stabilization techniques.
		Prohibiting removal of vegetation from dunes and slopes.
	Local Planning and Regulations	Identifying, mapping, or tracking erosion hazard areas.
		Developing and enforcing an erosion management plan.
		Developing site and building design standards.
	Education and Awareness Programs	Increasing awareness by disclosing location of high-risk areas to current and future property owners; offer mitigation technique information.
Other Extreme Weather	Structure and Infrastructure Projects	Increased costs of storm recovery and clean-up, including increased costs of snow removal due to increases in lake-effect snow.
		Protecting power lines through pruning trees.
		Burying overhead power lines or installing systems that allow small sections of power lines to fail rather than the complete system.

Appendix B: Discussion of Additional Impacts

The analysis presented in this report conservatively estimates that local governments could spend up to an additional $5.9 billion per year by midcentury to address just 10 likely impacts from climate change. These additional impacts and climate adaptation strategies will cost local communities more money to address and implement.

Increasing Temperatures

Infrastructure

Increased damage to water and sewer pipes due to more frequent freeze/thaw cycle.

More extreme weather events could lead to greater likelihood of electrical grid failure, which can impact water and sewer pipes heated with electricity. A Canadian study on the impacts of climate change in Ottawa, Canada was particularly worried about this prospect, noting that widespread reliance on electricity for space heating means that grid failure could lead to increased risk for frozen water pipes.[93]

Freeze/thaw cycles can impact the soil around pipe infrastructure. According to a study by the Environmental Law & Policy Center, higher temperatures and longer dry periods can reduce soil moisture and be harmful to buried pipe infrastructure due to subsidence.[94] Drier soil can sink into the ground unevenly, which can impact where pipes are set and potentially bend or break pipelines. In this case, local governments in charge of maintenance of pipelines will need to spend extra to maintain pipelines at current levels of effectiveness.

Pipeline failure can result in other costs associated with disruption of productivity. If work is interrupted by unexpected lack of water or sewage service, this can exact costs on local governments. Costs could be higher if these interruptions in work are associated with health care or other high-cost services with importance to the public sector. Deferred costs can create even higher costs for local governments down the road.

The American Society for Civil Engineering has assessed Ohio's drinking and wastewater systems, rating its drinking water system a D+ and its wastewater system a C-.[95] The Society highlights Ohio's aging distribution network as a weak spot for drinking water, projecting breaks to increase by 36 percent over the next 20 years and leading to a total of $13.4 billion in drinking water infrastructure needs over the next 20 years. The Society also cited the 2016 Clean Watersheds Needs Survey, saying Ohio needs $17 billion in new wastewater infrastructure investment in order to meet water quality and human health goals of the

93 Martin, Gary, and Patricia Ballamingie. "Climate change and the residential development industry in Ottawa, Canada." (2017).

94 "An Assessment of the Impacts of Climate Change on the Great Lakes," Environmental Law and Policy Center, Available Online: https://elpc.org/wp-content/uploads/2020/04/2019-ELPCPublication-Great-Lakes-Climate-Change-Report.pdf

95 "Ohio 2021 Report," American Society for Civil Engineers.

Clean Water Act. If infrastructure degrades quicker because of more frequent freeze/thaw cycles, these numbers could be higher.

Energy efficiency retrofits in public and private buildings and housing, including costs for the design and development of energy efficiency standards.

As temperatures increase, the demand for energy will increase for local governments. To reduce the price of energy, retrofits will need to be applied to public and private buildings and housing. A report by the Building America Retrofit Alliance to the Department of Energy estimated the average retrofit project in New Jersey cost roughly $14,000.[96] The majority of the homes in this study were within a few thousand dollars of this cost, but there were some outliers as well, with the most affordable project coming out to under $4,000 and the most expensive project approaching $36,000.

While energy efficiency retrofits should save operating costs in the long run, they require costs up front. Higher temperatures from climate change will lead to higher cooling costs, which means larger returns to energy efficiency retrofits. A 2011 study commissioned by the Department of Energy found that a $61,000 project to retrofit a 200,000-square foot office building would pay off in two years in a hot and humid climate.[97]

Also notable is the potential cost for development of energy efficiency standards, which would require a study to establish these standards. A study can have a wide range in potential costs, mostly determined by the size of the municipality and the extent to which the municipality is interested in complexity and detail in the study. The most likely range in costs, though, is for the study to be somewhere in the tens of thousands of dollars.

While improving energy efficiency has benefits that may justify costs for local governments, local governments may also be compelled to design and develop energy efficiency standards and retrofit buildings by federal regulations promulgated in future years. Also notable here is that these are costs that may fall on public and private sector interests. So if municipalities are supporting infrastructure (such as public transit hubs, etc.) that is meant to promote private economic development, they will likely be providing energy efficiency retrofits for those buildings as well. There is a possibility these could also apply to local government projects to support housing affordability depending on the specific regulations and legislation put in place in the future.

Public Health Projects

Increased demand for publicly financed air conditioning targeted to low-income families and public housing.

As local governments face rising costs to cool public buildings, their residents will face similar challenges at home. This poses equity issues as residents with higher incomes will find it easier to cool their homes than those experiencing poverty. The Centers for Disease Control and Prevention write in their Health Housing Reference Manual about

96 Liaukus, Christine, "Home Performance With Energy Star, Which Measures Get You 30% Savings?" Building America Retrofit Alliance. Available online: https://www.energy.gov/sites/prod/files/2014/03/f12/BA%20Webinar_Liaukus_3-19-14_0.pdf

97 Liu et al, "Advanced Energy Retrofit Guide: Practical Ways to Improve Energy Performance - Office Buildings," Pacific Northwest Research Laboratory, Prepared for the U.S. Department of Energy, September 2011.

the importance of air conditioning to reducing the risk of heat stroke.[98] Many local governments have committed themselves to providing livable housing and supporting residents in need of housing. Ensuring housing is sufficiently cool will be a larger part of their responsibility as the climate warms.

The Ohio Department of Development has a "Summer Crisis Program" that provides subsidies to low-income households struggling to pay for cooling during summer months.[99] Programs such as these can ensure families have the resources they need to keep their homes cool while also offering support to those individuals experiencing poverty. The national average cost to install central air conditioning is $5,700 and is likely much higher for a large project, meaning costs to cool public housing could add up for local governments.[100]

Additionally, public housing units that do not provide sufficient cooling for residents could pose a safety hazard for residents and fall short of the goal of providing livable housing. Providing air conditioning to ensure that units are livable under conditions of increased heat could pose more costs for local governments unless they decide to defer these to state or federal entities, potentially putting their residents in danger. Doing so could leave residents with no support at a time when heat conditions become more dangerous for them.

Controlling the increase of vector-borne illness education and physical and chemical controls for ticks and mosquitoes.

Warm weather can facilitate the spread of "vector-borne illness" that spreads through insects such as ticks and mosquitoes, which thrive in warm environments. The Centers for Disease Control and Prevention reports that climate change increases the number and geographic range of disease-carrying insects and ticks. Last year, the Ohio Department of Health reported three cases of West Nile Virus among humans along with over 400 cases of Lyme Disease.[101]

In order to combat the spread of vector-borne illness, local governments will need to resort to education programs. Funding these education programs could end up being costly depending on the spread of these diseases and the extent to which climate change facilitates new activity among people in the state that could increase exposure to ticks and mosquitoes.

Local governments will also be tasked with curbing vector-borne illness by using physical and chemical controls for ticks and mosquitoes. The Centers recommend local mosquito control programs for control of vector-borne illness in an area.[102]

98 "Healthy Housing Reference Manual," Centers for Disease Control and Prevention, Healthy Housing Reference Manual

99 "Summer Cooling Program," Individual | Energy Assistance Programs, Ohio Department of Development, Available Online at https://development.ohio.gov/is/is_heapsummer.htm

100 "How much does it cost to install central air?" Home Advisor, Available Online: https://www.homeadvisor.com/cost/heating-and-cooling/install-an-ac-unit/

101 "Ohio Vectorborne Disease Surveillance Update," Zoonotic Disease Program, Ohio Department of Health, August 27, 2021, Available Online: https://odh.ohio.gov/know-our-programs/zoonotic-disease-program/news/vectorborne-disease-update

102 "Why Is Mosquito Control Important?" Centers for Disease Control and Prevention, October 6, 2020, Available Online: https://www.cdc.gov/mosquitoes/mosquito-control/why-is-mosquito-control-important.html

These control programs could present a range of different costs. For example, Bartlesville, Oklahoma, spends 34 cents per resident per month on mosquito control.[103] A 1997 survey found there were 345 mosquito control districts in the United States spending about $230 million to control mosquito nuisances.[104] This number could climb higher if temperature conditions continue to improve for mosquitoes.

Treating victims of vector-borne illness.

Local health departments play a large part in promoting public health in the state of Ohio. Vector-borne illnesses are often the result of local environmental factors, putting local governments in the most advantageous position to abate the threat of vector-borne illness. The Centers for Disease Control and Prevention reports that climate change could increase the number and geographic range of disease-carrying insects and ticks.[105] This could lead to more victims of vector-borne illness.

A 2005 CDC study of West Nile Virus found treatment of West Nile Virus during an outbreak in Sacramento cost about $6,000 per inpatient and $33,000 per outpatient.[106] This does not include lost productivity costs, which would mainly accrue directly to employers, but may be important to local governments if teachers or other public sector workers become exposed to West Nile. How these are split between state insurers, private governments, and local governments will depend on how financing is arranged for health care, which also may be impacted by vector borne illness outbreaks.

A high-profile study conducted by Johns Hopkins University researchers found Lyme disease contraction is associated with about $3,000 higher medical costs per patient.[107] These costs may not necessarily accrue to the local governments where people live, but widespread outbreaks of these diseases could certainly strain local health departments. The Mayo Clinic recommends antibiotics for treating Lyme disease.[108] Health insurance carriers often only cover the first thirty days of treatment, which could mean victims of Lyme disease would turn to other providers of health care like local governments for assistance.

Increase in asthma attacks requiring hospitalization (resulting from increased heat and ground level ozone and the increase in airborne allergens due to lengthened growing season).

The Montreal Protocol has been effective at reducing ozone worldwide, but higher temperatures could potentially lead to both a resurgence in ozone and an increase in

103 "Q&A: Mosquito control program costs, revenues," City of Bartlesville, July 30, 2019, Available Online: https://www.cityofbartlesville.org/qa-mosquito-control-program-costs-revenues/

104 AMCA. 1999. Directory of Mosquito Control Agencies in the United States, American Mosquito Control Association.

105 "Climate Change Increases the Number and Geographic Range of Disease-Carrying Insects and Ticks," Centers for Disease Control and Prevention, Available Online: https://www.cdc.gov/climateandhealth/pubs/vector-borne-disease-final_508.pdf

106 Barber LM, Schleier JJ, Peterson RK. Economic Cost Analysis of West Nile Virus Outbreak, Sacramento County, California, USA, 2005. Emerging Infectious Diseases. 2010;16(3):480-486. doi:10.3201/eid1603.090667.

107 Adrion, Emily R. et al, "Health care costs, utilization and patterns of care following Lyme disease." PloS one 10, no. 2 (2015): e0116767.

108 "Lyme Disease," Mayo Clinic, October 24, 2020, Available Online: https://www.mayoclinic.org/diseases-conditions/lyme-disease/diagnosis-treatment/drc-20374655

allergens that can trigger asthma attacks. Asthma-related hospitalization could strain hospitals, local health departments, and emergency services, which could lead to higher costs for local governments in charge of them.

Severe asthma attacks can balloon into life-threatening emergencies. According to a guide released by the Harvard T.H. Chan School of Public Health, climate change increases air pollution, allergies, and wildfires, all of which exacerbate asthma attacks.[109] American Health and Drug Benefits reports that the average asthma attack costs $400 for an emergency room visit and $5,000 for an inpatient care visit, costs that could stack up if local governments have to pay them for one reason or another.[110]

Reducing the urban heat island by planting trees to provide shade in parking lots, school playgrounds, residential streets, and public right-of-ways.

The way cities absorb heat means that temperature increases brought about by climate change will likely be higher in cities than outside of them.[111] According to the United States EPA, trees and plants can cool the local environment, making vegetation an effective tool for reducing urban heat islands.[112] They cite a study that found that annual tree expenditures in cities range from $15 to $65 per tree in cities surveyed, with pruning being the largest expenditure.

A nationwide survey of 5,700 communities released earlier this year found that low-income city blocks have less tree cover than high-income blocks.[113] These researchers found that low-income blocks have 15 percent less tree cover and are 1.5 degrees Celsius warmer on average than high-income blocks. As temperatures increase from climate change, these disparities will only widen over time. The study estimated a cost of nearly $18 billion to close the gap between low- and high-income blocks. Reducing heat island effect in low-income communities could be a key step in addressing a disparity of heat-related health impacts made worse by climate change.

109 "Climate Change and Asthma," Harvard T.H. Chan School of Public Health, Available Online: https://www.hsph.harvard.edu/c-change/subtopics/climate-change-and-asthma/

110 "Inpatient Treatment of Asthma Is Costly: $5000 per Hospitalization Calls for Proper Office Management," American Health & Drug Benefits.

111 Harvey, Chelsea, "Urban Heat Islands Mean Warming Will Be Worse in Cities," E&E News, Scientific American, November 21, 2019, Available Online: https://www.scientificamerican.com/article/urban-heat-islands-mean-warming-will-be-worse-in-cities/

112 "Using Trees and Vegetation to Reduce Heat Islands," United States Environmental Protection Agency, Available Online: https://www.epa.gov/heatislands/using-trees-and-vegetation-reduce-heat-islands

113 McDonald, Robert I. et al, "The tree cover and temperature disparity in US urbanized areas: Quantifying the association with income across 5,723 communities." PloS one 16, no. 4 (2021): e0249715.

Extreme Precipitation and Flood Protection

Structure and Infrastructure Projects

Removing, relocating, acquiring, or demolishing structures from flood-prone areas to minimize future flood losses.

According to the United States EPA, climate change may cause river floods to become larger and more frequent in some places.[114] A 2020 study of flood risk by a consortium of scientists and engineers from academic institutions including University of California-Berkeley, George Mason University, and Rutgers University concluded that eight percent of Ohio properties are at risk for flooding and are concentrated in Ohio's major urban areas of Cincinnati, Cleveland, and Columbus.[115]

It is often up to local governments to take on the job of removing, relocating, acquiring, and demolishing structures that are dilapidated or not economically viable, hence the rise of land banks and the growth of affordable housing policy among local governments. Luckily, the First Street study does not anticipate a larger proportion of Ohio's properties becoming subject to flood risk over the next thirty years, so these costs are not likely to increase because of more properties being put at risk. That being said, interruption of global supply chains for building materials due to extreme weather could make these projects more costly.

FEMA lists structure demolition and relocation as an eligible mitigation measure for flood risk.[116] The average home demolition costs $18,000, so this can be a costly intervention for reduction of flood risk.[117]

Installing, rerouting, increasing capacity, or implementing routine cleaning plans for the storm drainage system.

Storm drainage systems are local governments' primary tool for reducing the direct impact of storms on public health, safety, and property within their bounds. According to the United States EPA, climate change is likely to lead to more frequent and intense storms and more extreme flooding events, which can put a pressure on local infrastructure by increasing storm runoff.[118]

The Agency suggests green infrastructure strategies, use of climate and land use data, and natural infrastructure as tactics for managing increased stormwater runoff. Installing, rerouting, increasing capacity, and implementing routine cleaning plans of storm drainage

114 "Climate Change Indicators: River Flooding," United States Environmental Protection Agency, Available Online: https://www.epa.gov/climate-indicators/climate-change-indicators-river-flooding

115 "Flood Factor: Defining America's Past, Present, and Future Flood Risk," First Street Foundation, 2021, Available Online: https://firststreet.org/flood-factor/

116 "Eligible Mitigation Measures," Federal Emergency Management Agency, Available Online: https://www.fema.gov/pdf/plan/floodplain/fema301_section5.pdf

117 "How Much Does It Cost To Demolish A House?," Home Advisor, August 23, 2021, Available Online: https://www.homeadvisor.com/cost/landscape/house-demolition/

118 Climate Adaptation and Stormwater Runoff, Climate Change Adaptation Resource Center (ARC-X), United States Environmental Protection Agency, May 26, 2021, Available Online: https://www.epa.gov/arc-x/climate-adaptation-and-stormwater-runoff

systems will all cost local governments more money as time goes on if storms grow more severe or frequent over time.

One estimate from a construction company puts the cost of a storm trench or channel at $150 per linear foot and costs can run anywhere from a few thousand dollars to a few million dollars depending on the project.[119] According to Pennsylvania State University, storm runoff rain garden construction can cost $7 to $11 per cubic foot.[120] More comprehensive systems could cost even more depending on the size and complexity of the project.

Adding extra culverts, increasing dimensions of existing culverts, or implementing routine cleaning and repairing.

A culvert is a structure that allows water to flow underneath a road, trail, sidewalk, railroad, or other obstruction. These serve the purpose of allowing for infrastructure to function alongside already-existing streams and waterways. The same way that sewer drainage systems will be impacted by more frequent and intense storms, culverts may need to be added in new places as these storms create new streams and waterways. They also may increase the yield down current waterways, which could lead to unsafe conditions if the size of a culvert is not large enough. Different patterns in storms may also lead to more frequent cleaning and repair. Modifications and increase in routine maintenance are costs that will fall on local governments if they wish their infrastructure to stay at current levels of operation, preserve public safety, and meet regulations required by other governments.

A report by the University of Virginia states that culvert systems are built with an assumption that rain patterns will stay the same over time but that climate change is changing rainfall patterns.[121] Culverts are a key part of Ohio's storm water management system, so much so that the Ohio Department of Transportation publishes a culvert management manual to aid in inventory, management, and inspection of culverts.[122] A USDA document puts the costs of culverts at anywhere from $6 to $74 per foot.[123]

Inspecting and maintaining drainage systems and flood control structures (dams, levees, ice-jam preventers, etc).

Dams, levees, and ice-jam preventers are other pieces of infrastructure likely to be impacted by climate change. Heavy rainfall, changes in snow cover and snowmelt, and shifting vegetation and soil moisture will impact the effectiveness and safety of dams as

119 "Costs of a Storm Sewer System," Park Enterprise Construction Co. Inc., 2018, Available Online: https://parkenterpriseconstruction.com/2020/07/06/what-is-the-cost-of-a-storm-sewer-system/

120 "What Will My Stormwater Project Cost?," Penn State Extension, April 19, 2018, Available Online: https://extension.psu.edu/what-will-my-stormwater-project-cost

121 Morsy, Mohamed M. et al, "Incorporating Potential Climate Change Impacts in Bridge and Culvert Design," No. FHWA/VTRC 20-R13. 2019.

122 "Culvert Management Manual," Ohio Department of Transportation, Available Online: https://www.dot.state.oh.us/Divisions/Engineering/Structures/standard/Maintenance/Documents/CMM_12-2003.pdf

123 "Drainage and Incidental Construction," USDA, Available Online: https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5247320.pdf

they exist today.[124] Climate change could also impact the probability a flood will occur, which will impact the safety of levees as they are built now.[125] Changing patterns of glacial melt will impact the effectiveness of ice-jam preventers.[126] All these changes will require investment in new infrastructure in order to ensure public safety. These investments will likely fall on local governments.

Flooding is a natural phenomenon. The intensification of this phenomenon, however, is being driven by climate change.[127] The intensification of flooding cycles will require local governments to rebuild and overhaul their flood control systems in order to account for this change.[128] If inspections show flood control structures are not prepared for intensified flooding, costs could pile up for local governments. For instance, a recent world survey of flood prevention costs published in the journal Water found that floodwalls in the United States cost $5.5 million per kilometer in 2016 dollars, or $8.9 million per mile.[129]

Inspecting bridges in order to identify and/or implement repairs or retrofits or cleaning under low bridges.

Bridges often act as very large culverts, with water running underneath them. A 2021 review of the potential impacts of climate change on the safety and performance of bridges finds seven major categories of risks to bridges imposed by climate change: durability, serviceability, geotechnical, increased demand, accidental loads, extreme natural events, and operational risks.[130] The strain that extreme precipitation and flood protection place on low bridges qualifies as a cost brought on by extreme natural events.

The review referenced above says that increased intensity and frequency of storms is likely due to climate change and that lifting and unseating of bridge decks is a common failure mechanism observed during extreme weather events. It also notes that flooding is one of the costliest impacts of climate change on bridges, costs that are likely to be borne by local governments in charge of maintaining these bridges.

A recent study found most of the main load carrying girders they studied could reach their capacity when subjected to service load and future climate changes.[131] Among U.S. states, Ohio has more bridges than any other state besides Texas, with 144 million square

124 Fluixá-Sanmartín, Javier et al, "Climate change impacts on dam safety." Natural Hazards and Earth System Sciences 18, no. 9 (2018): 2471-2488.

125 Vahedifard, Farshid et al, "Levee Fragility Behavior under Projected Future Flooding in a Warming Climate." Journal of Geotechnical and Geoenvironmental Engineering 146, no. 12 (2020): 04020139.

126 Xinlei, Guo et al, "Progress and Trend in the Study of River Ice Hydraulics." Chinese Journal of Theoretical and Applied Mechanics, 53, no. 3 (2021): 655-671.

127 Cohen, Steve, "Midwestern Floods, Climate Resiliency, and the Green New Deal," State of the Planet, Columbia Climate School, March 25, 2019, Available Online: https://news.climate.columbia.edu/2019/03/25/midwestern-floods-climate-resiliency-green-new-deal/

128 Cohen, Steve, "Floods, Infrastructure and Climate Change," State of the Planet, Columbia Climate School, June 3, 2019, Available Online: https://news.climate.columbia.edu/2019/06/03/floods-infrastructure-climate-change/

129 Aerts, Jeroen CJH. "A review of cost estimates for flood adaptation." Water 10, no. 11 (2018): 1646.

130 Nasr, Amro et al, "A review of the potential impacts of climate change on the safety and performance of bridges." Sustainable and Resilient Infrastructure 6, no. 3-4 (2021): 192-212.

131 Palu, Susan, and Hussam Mahmoud. "Impact of climate change on the integrity of the superstructure of deteriorated US bridges." Plos one 14, no. 10 (2019): e0223307.

feet of deck area across the state.[132] While the state government handles a lot of bridge maintenance throughout Ohio, bridges in local areas may take local involvement as well. According to the American Road & Transportation Builders Association, Ohio has identified needed repairs on nearly 3,300 bridges at an estimated cost of $2.4 billion.[133]

Resurfacing roads with more permeable pavement and concrete to better handle increased rainfall.

More frequent and intense storms can increase stormwater runoff.[134] A strategy for dealing with increased rainfall is to resurface roads with pavement and concrete that drain through the road rather than sloughing off to the sides and collecting. A study conducted by researchers at Southern Illinois University and University of Nevada, Las Vegas found this can be an effective strategy for managing changes in urban stormwater amounts due to climate change.[135] County Health Rankings & Roadmaps rates permeable pavement projects at its highest level of scientific evidence, saying there is scientific support for claims that permeable pavement reduces water runoff and water pollution and has potential benefits to reduce urban heat island effects, crashes, soil erosion and flooding and to increase wildlife habitat.[136]

Local governments working to upgrade their current roads to be permeable will have to pay for materials and labor, a cost which will likely not be picked up by state or federal partners. On top of this, they will have to pay for the permeable pavement, which can cost anywhere from $0.50 to $40 per square foot and is usually more expensive than asphalt.[137]

Elevating structures above the base flood elevation (BFE), or relocating utilities, water heaters, etc. above BFE.

If flood levels become more volatile, it will impact not only roads and bridges, but also existing structures and public utilities as well. Two utility systems that could be especially worrisome for local governments if threatened are sewage systems and stormwater drainage. These are two systems that depend crucially on the flow of water. If flooding backs up a sewage system, that can stop drainage systems from working. At best, flooding will slow the drainage of toxic backup. At worst, it will send toxins back into businesses and residences. If stormwater drainage systems are backed up, floodwater can also flow backwards out of a drainage system onto the street rather than flowing out of the stormwater drainage system like it is designed to do. Relocation of sewage and stormwater runoff systems is an expensive proposition for local governments.

132 Weykamp, Peter et al, "Best Practices in Bridge Management Decision-Making." Arora and Associates, PC, Lawrenceville, NJ (2009).

133 "National Bridge Inventory: Ohio," American Road & Transportation Builders Association, March 11, 2021, Available Online: https://artbabridgereport.org/state/profile/OH

134 "Climate Adaptation and Stormwater Runoff," United States Environmental Protection Agency.

135 Thakali, Ranjeet et al, "Management of an urban stormwater system using projected future scenarios of climate models: a watershed-based modeling approach." Open Water 5, no. 2 (2018): 1.

136 "Permeable pavement projects," What Works for Health, County Health Rankings & Roadmaps, December 7, 2017, Available Online: https://www.countyhealthrankings.org/take-action-to-improve-health/what-works-for-health/strategies/permeable-pavement-projects

137 "How Much Does Permeable Pavement Cost?," HomeAdvisor, Available Online: https://www.homeadvisor.com/cost/garages/permeable-pavement/

Water heating units located inside structures are also vulnerable to flooding. If a water heater is within a building, it is often located at the basement level. Submerging a water heater in floodwaters can lead to penetration of the heater's electronic ignitor and its components or entrance into the water heater chambers via gas flows. Water seeping into a gas chamber and traveling through a gas line can even cause pilot lighting and explosion.

According to the United States EPA, floods have become larger in rivers and streams across the Midwest.[138] Elevating structures is such a staple of flood risk mitigation that the FEMA has an entire guide on how to reduce risk for structures that cannot be elevated.[139] A study published in the journal Water offered a wide range of different costs to elevate a building, from $19,000 to $190,000 per structure.[140] Wherever it falls in this range, it is an expensive proposition.

Floodproofing inside of municipal buildings, for example by installing check valves, sump pumps, or backflow prevention devices.

Local governments may be forced to install new equipment to floodproof public buildings and make them more hardy against the threat of new flooding brought on by climate change. This could include offices for city staff, police and fire stations, and service centers for city programs. The C40 Climate Leadership Group lists flooding as one of the top three risks posed by climate change to municipal buildings, alongside extreme heat and drought.[141]

Check valves, sump pumps, and backflow valves are all included as technologies suggested for floodproofing in FEMA.[142] A check valve is a one-way valve that allows water to flow out of an area but not back in, thus reducing the threat of flood damage. A sump pump is a pump submerged in a water-collecting "sump basin" located in a basement. It pumps water out of the basin as flooding occurs and deposits it outside of the building. According to a recent study in the journal Water, a check valve costs on average about $1,100 in 2009 dollars and a sump pump costs on average $1,700, meaning these are not the most expensive interventions, but also not cheap, especially for small local governments.[143]

Floodproofing wastewater treatment facilities located in flood hazard areas.

Wastewater treatment is one of the core public health services of local governments, playing a key role in the prevention of gastroenteritis, meningitis, fevers, and diarrhea

138 "Climate Change Indicators: River Flooding," United States Environmental Protection Agency, Available Online: https://www.epa.gov/climate-indicators/climate-change-indicators-river-flooding

139 "Reducing Flood Risk to Residential Buildings That Cannot Be Elevated," Federal Emergency Management Agency, September 2015, Available Online: https://www.fema.gov/sites/default/files/2020-07/fema_P1037_reducing_flood_risk_residential_buildings_cannot_be_elevated_2015.pdf

140 Aerts, "A review of cost estimates for flood adaptation."

141 "Reducing climate change impacts on municipal buildings," Policy Briefs, C40 Knowledge, July 2019, Available Online: https://www.c40knowledgehub.org/s/article/Reducing-climate-change-impacts-on-municipal-buildings?language=en_US

142 "Floodproofing Non-Residential Buildings," Federal Emergency Management Agency, July 2013, Available Online: https://www.fema.gov/sites/default/files/2020-07/fema_p-936_floodproofing_non-residential_buiildings_110618pdf.pdf

143 Aerts. "A review of cost estimates for flood adaptation."

among residents.[144] Researchers say that climate change will lead to more extreme weather events and earlier snowmelt runoff, which will itself lead to more untreated sewer overflows and increased flooding.[145] Flooding of wastewater treatment facilities could leave them inoperable and put them at serious risk. Iowa City went as far as to close a vulnerable wastewater treatment facility to prevent a potential future hazard.[146]

Floodproofing of wastewater treatment facilities is likely to mirror floodproofing challenges for other municipal structures. Check valves and sump pumps will be used in places, but backup risk is much more sensitive in a wastewater treatment plan with toxic wastewater leading to even larger threats to public health and safety than in a municipal office structure.

The United States EPA notes that upgrades to wastewater treatment systems are often expensive.[147] Other related costs are incurred to housing and other structures within-home septic systems, which are vulnerable to flooding themselves.

Floodproofing water treatment facilities located in flood hazard areas.

Water treatment facilities are also susceptible to flood risk. The United States EPA suggests construction of new infrastructure, modeling climate risk, modifying land use, monitoring operational capabilities, climate change planning, and repair and retrofitting of facilities as options for local governments working to mitigate flood risk for water treatment plants.[148] Each of these options are likely to levy new costs on local governments, with new infrastructure and retrofit being the most expensive.

Heavier rain storms can lead to more contaminants in drinking water, which may make treatment difficult.[149] The United States EPA identifies a range of interventions like pumps and sandbags for reducing water encroachment into a facility.[150] Lincoln, Nebraska spent $300,000 on a flood mitigation project to protect the city's water treatment facility.[151]

144 Ikehata, Keisuke. "Hazardous agents in wastewater: public health impacts and treatment options for safe disposal and reuse." In Wastewater Reuse and Management, pp. 165-191. Springer, Dordrecht, 2013.

145 Zouboulis, Anastasios, and Athanasia Tolkou. "Effect of climate change in wastewater treatment plants: reviewing the problems and solutions." In Managing water resources under climate uncertainty, pp. 197-220. Springer, Cham, 2015.

146 "Climate Impacts on Water Utilities," United States Environmental Protection Agency, Available Online: https://www.epa.gov/arc-x/climate-impacts-water-utilities

147 "Wastewater Treatment Plants," The Sources and Solutions: Wastewater, Nutrient Pollution, United States Environmental Protection Agency, March 1, 2021, Available Online: https://www.epa.gov/nutrientpollution/sources-and-solutions-wastewater

148 "Storms and Flooding," Climate Impacts on Water Facilities, Climate Change Adaptation Resource Center, United States Environmental Protection Agency, August 31, 2021, Available Online: https://www.epa.gov/arc-x/climate-impacts-water-utilities#storms

149 Fecht, Sarah, "How Climate Change Impacts Our Water," Columbia Climate School, September 23, 2019, Available Online: https://news.climate.columbia.edu/2019/09/23/climate-change-impacts-water/

150 "Flood Resilience: A Basic Guide for Water and Wastewater Facilities," United States Environmental Protection Agency, Available Online: https://www.epa.gov/sites/default/files/2015-08/documents/flood_resilience_guide.pdf

151 "Mitigation of Essential Structures Helps to Keep Water Treatment Plant Open: Full Mitigation Best Practice Story," Federal Emergency Management Agency, Available Online: https://www.fema.gov/case-study/mitigation-essential-structures-helps-keep-waste-water-treatment-plant-ope

Protecting emergency operations by upgrading or moving all emergency operations centers, police stations, and fire department facilities outside of flood-prone areas.

Public safety spending in the form of police and fire protection systems are a major portion of local government spending. These services rely heavily on quick response times and the ability to operate around the clock and throughout the week, so flooding of these facilities could hamper public safety responses at times they are needed most.

One analysis of climate change risk to municipal infrastructure brings up another danger to flooding of police stations in particular: potential loss of records, anything from cold case records to unprocessed rape kits.[152] Policing operations depend on documentation and record-keeping and loss of these records can pose a serious threat to public safety and the criminal justice system as a whole.

Upgrading or relocating emergency response services is not a cheap undertaking and will likely fall on local governments to do so or risk danger to public health and safety. Emergency operation centers, police stations, and fire stations will require many of the same flood protection measures as other municipal buildings, but may be even more critical since their failure has such dangerous implications.

Protecting critical and emergency facilities by requiring all critical facilities be built one foot above the 500-year flood elevation (to meet requirements of Executive Order 11988).

The United States Department of Health and Human Services emphasizes that climate change and the variability of extreme weather events associated with it will make hazards and risk to critical and emergency facilities harder to predict.[153] Local governments are subject to compliance with state and federal regulations. For example, Executive Order 11988, promulgated by the Carter Administration, governs how floodplains are managed throughout the United States.[154] In April 2013, the Federal Interagency Hurricane Sandy Rebuilding Task Force announced a new federal flood risk reduction standard that required elevation or floodproofing at one foot above the base flood elevation.[155]

If local governments are to meet these federal requirements, it may mean relocation of government operations or expensive improvements to current structures to provide extra floodproofing in the face of extreme weather, rain, and flooding brought about by climate change.

152 Rahman, Md Mostafizur, and Ishrat Islam. "Exposure of urban infrastructure because of climate change-induced flood: lesson from municipal level planning in Bangladesh." Ecofeminism and Climate Change (2020).

153 Guenther, R., and J. Balbus. "Primary protection: enhancing health care resilience for a changing climate." US Department of Health and Human Services (2014).

154 "Executive Order 11988--Floodplain management," Executive Orders, Federal Register, National Archives, August 15, 2016, Available Online: https://www.archives.gov/federal-register/codification/executive-order/11988.html

155 "Reevaluation of the 1 Percent Chance or 100-Year Flood Standard," Updates to Floodplain Management and Protection of Wetlands Regulations To Implement Executive Order 13690 and the Federal Flood Risk Management Standard, Federal Register: The Daily Journal of the United States Government, National Archives, Available Online: https://www.federalregister.gov/documents/2016/08/22/2016-19810/updates-to-floodplain-management-and-protection-of-wetlands-regulations-to-implement-executive-order

Relocation is likely to be the largest cost since it will require use of entirely new facilities. According to one estimate, the cost to raise a home above a flood zone is nearly $33,000.[156] These costs would likely be higher for an emergency facility, which is usually much more complex than a home. Retrofitting could also be very expensive, though, as installation of flood control infrastructure is costly, not only for materials, but for the labor required to conduct the installation itself.

Protecting critical and emergency facilities from floods using any other technique, for example, raising components above BFE, installing pumping systems or back-up generators for pumping, building dikes or stabilizing banks.

Access to critical and emergency facilities are vital to public health — especially during a public safety emergency such as a natural disaster with widespread flooding. If critical and emergency facilities cannot be reached or are rendered inactive by flooding, the public not only has to deal with a natural disaster, but they must do so without the resources to respond to that disaster.

Improving critical and emergency facilities so they are operational during times of extreme rain and flooding can be expensive for local governments. One strategy is to raise key components above the base flood elevation (BFE). One presentation by the Association of Floodplain Managers estimated the cost of moving a 2,000 square foot structure two feet above base flood elevation at $4,700.[157]

Other strategies for reducing flood risk for critical and emergency facilities have costs as well. Current cost estimates for a well pump replacement is $1,600.[158] Whichever approach local governments take to mitigating flood risk for critical and emergency facilities, they are likely to have costs, at least in the short-term. FEMA also lists dikes and floodproofing as tools for flood damage reduction.[159] A survey of flood management costs in the journal Water found river dikes in Canada were around the same cost as deployable floodwalls in the United States: $5.5 million per kilometer in 2016 dollars, or $8.9 million per mile.[160]

Constructing floodwalls, small berms, revetments, bioengineered bank stabilization or other small structural mitigation measures.

The United States EPA reports that flooding increased in five regions of the state of Ohio from 1965 to 2015 and did not decrease anywhere in the state.[161] Increase in flooding was significant in northwest Ohio in particular. Outside of the aforementioned examples

156 "What Is The Cost To Raise A House Above The Flood Zone?," Upgraded Home, 2021, Available Online: https://upgradedhome.com/what-is-the-cost-to-raise-a-house-above-the-flood-zone/

157 "The Costs & Benefits of Building Higher," Association of Floodplain Managers, Available Online: https://sema.dps.mo.gov/programs/floodplain/documents/costs-benefits-flier.pdf

158 "How Much Does It Cost To Install Or Replace A Well Pump?," HomeAdvisor, August 6, 2021, Available Online: https://www.homeadvisor.com/cost/plumbing/replace-a-well-pump/

159 "Flood Damage Reduction Strategies and Tools," Federal Emergency Management Agency, Available Online: https://training.fema.gov/hiedu/docs/fmc/chapter%207%20-%20flood%20damage%20reduction%20strategies%20and%20tools.pdf

160 Aerts, "A review of cost estimates for flood adaptation."

161 "Change in the Magnitude of River Flooding in the United States, 1965–2015," Climate Change Indicators: River Flooding, United States Environmental Protection Agency, Available Online: https://www.epa.gov/climate-indicators/climate-change-indicators-river-flooding

of targeted flood management, local governments have obligations for other structural mitigation measures for addressing flood abatement in their communities.

The U.S. Army Corps of Engineers highlights floodwalls as a best practice strategy for dam and levee safety.[162] Floodwalls can have a range of costs depending on the size of the project, but one current estimate puts floodwalls at an average of $4.10 per square foot of flood area.[163] The cost of deployable floodwalls in the United States has been reported by a survey in the journal Water at $5.5 million per kilometer in 2016 dollars, or $8.9 million per mile.[164]

Possibly less intrusive than a formal floodwall is a small berm, or a rounded mound of soil used to hold floodwaters at bay. A berm to divert water usually runs somewhere in the thousands of dollars when installed at the residential level and could be more expensive at the community level.[165] A revetment is an installation of masonry or some other material used to hold off flooding or reduce erosion on a bank. These can be very expensive, with some estimates coming in at $90 a foot.[166]

Natural Systems Protection

Protect and enhance natural floodplain mitigation features (such as wetlands, dunes, and vegetative buffers) to help prevent flooding in other areas.

Flooding has been an increasingly expensive problem in recent years, with notable river flooding in 2019 along the Missouri and Mississippi rivers costing billions of dollars in damage.[167] Natural floodplain mitigation features like wetlands, dunes, and vegetative buffers are well suited for controlling the risk of flooding, but protecting these features can be costly.

Specifically, the United States EPA notes the importance of wetlands in flood protection, saying they trap and then slowly release floodwater.[168] According to a seminar delivered to the EPA, the cost of restoring and preserving wetlands ranges from $150 to $6,100 per acre.[169]

162 "Floodwalls: Best Practices in Dam and Levee Safety Risk Analysis," US Army Corps of Engineers, July 2019, Available Online: https://www.usbr.gov/ssle/damsafety/risk/BestPractices/Presentations/E8-FloodwallsPP.pdf

163 "How much does it cost to build a flood wall?," 18 May, 2021, Available Online: https://everythingwhat.com/how-much-does-it-cost-to-build-a-flood-wall

164 Aerts, "A review of cost estimates for flood adaptation."

165 "Building a Berm to Divert Water," How Much Does It Cost To Remove & Drain Standing Water?, HomeAdvisor, Available Online: https://www.homeadvisor.com/cost/disaster-recovery/remove-standing-water/

166 Allen, Jennifer, "Living Shoreline Cost Depends on Site, Size," CostalReview.org, December 17, 2019, Available Online: https://coastalreview.org/2019/12/affordability-key-in-pricing-living-shorelines/

167 "How Nature Can Help Reduce Flood Risks," The Nature Conservancy, January 28, 2020, Available Online: https://www.nature.org/en-us/what-we-do/our-priorities/tackle-climate-change/climate-change-stories/natures-potential-reduce-flood-risks/

168 "Flood Protection," Incorporating Wetland Restoration and Protection in Planning Documents, Wetlands, United States Environmental Protection Agency, January 29, 2021, Available Online: https://www.epa.gov/wetlands/incorporating-wetland-restoration-and-protection-planning-documents

169 Hansen, LeRoy, "Seminar: Environmental Targeting: Some Spatial Estimates of the Costs and Benefits of Restoring and Protecting Wetlands," June 25, 2014, Available Online: https://www.epa.gov/environmental-economics/seminar-environmental-targeting-some-spatial-estimates-costs-and-benefits

These estimates are mirrored by the USDA, which reports that the per-acre cost to restore and preserve new wetlands ranges from the hundreds to thousands of dollars.[170]

Local Planning and Regulations

Developing a floodplain or coastal zone management plan.

Climate change projections indicate a likelihood for more frequent and heavy flooding, with size, depth, and damages of floods likely to increase.[171] Floodplain management is a community-based effort designed to prevent or reduce the risk of flooding.[172] A floodplain management plan contains four phases: mitigation, preparedness, response, and recovery.[173] Development of such a plan is a key step in minimizing flood risk in communities that are both used to flooding and communities where flooding will be a new occurrence to contend with because of climate change.

Like any thorough planning process, development of a floodplain management plan has costs. Local governments interested in developing a floodplain management plan that incorporates localized flooding conditions will need to employ professional engineers, planners, and possibly even environmental consultants in the process. Staff time can also factor into the overall cost. FEMA provides some resources for communities interested in engaging in floodplain management.[174] Depending on the size of the community and the quality of the study, a floodplain management plan could cost between tens of thousands to hundreds of thousands of dollars.

Adopting a stormwater management or drainage plan, or completing a stormwater drainage study to address flooding/erosion related to rainwater or snowmelt.

According to the United States EPA, water resources are impacted by climate stressors such as increasing temperatures, changing precipitation patterns, and extreme weather,[175] which impact how stormwater is managed. The EPA encourages intentional planning by local leaders to mitigate the issues with stormwater drainage caused by climate change.[176]

170 Hansen, LeRoy, "Wetlands Benefits and Costs Vary With Location," Amber Waves, Economic Research Service, U.S. Department of Agriculture, May 4, 2015, Available Online: ers.usda.gov/amber-waves/2015/may/wetlands-benefits-and-costs-vary-with-location/

171 Christin, Zachary, and Michael Kline. "Why we continue to develop floodplains: Examining the disincentives for conservation in federal policy." Earth Economics 6 (2017).

172 "Floodplain Management," Federal Emergency Management Agency, May 11, 2021, https://www.fema.gov/floodplain-management

173 Pichelmann, Rachel, "4 Steps to an Effective Flood Management Plan," Short Elliott Hendrickson Inc., 2021, Available Online: https://web.archive.org/web/20210512071239/https://www.sehinc.com/news/4-steps-effective-flood-management-plan

174 "Floodplain Management," Federal Emergency Management Agency.

175 "Stormwater Management In Response To Climate Change Impacts: Lessons From The Chesapeake Bay And Great Lakes Regions (Final Report)," United States Environmental Protection Agency, May 19, 2016, Available Online: https://cfpub.epa.gov/ncea/global/recordisplay.cfm?deid=310045

176 "National Menu of Best Management Practices (BMPs) for Stormwater," National Pollutant Discharge Elimination System (NPDES), United States Environmental Protection Agency, August 28, 2020, https://www.epa.gov/npdes/national-menu-best-management-practices-bmps-stormwater

A stormwater management plan attempts to reduce runoff of rainwater and melted snow into streets, lawns, and other sites and to improve water quality.[177] Many states require stormwater management plans and climate change may prompt local governments to update existing plans. Changing weather patterns from climate change might make past stormwater management plans obsolete, requiring new plans to be developed. Similarly, drainage plans will likely need to be updated to account for increased flooding and precipitation. These sorts of plans may even require stormwater drainage studies so planners can better understand the current and expected future dynamics around stormwater drainage.

Much like floodplain management plans, stormwater management or drainage plans and studies are costly to develop. Professional planners, engineers, current staff, and policymakers will all likely be engaged in the planning process, requiring time and money that could be spent on other projects. Planning can have a range of costs that run from the tens of thousands to the hundreds of thousands of dollars, depending on the scale of the project.

Adopting, applying and enforcing building codes to ensure buildings can withstand flooding.

Building codes are among the most powerful tools municipalities have to impact the lives of their residents. As climate change increases the chance of flood risk, building codes are not keeping up with the changes in flood risk.[178] FEMA lays out best practices for building in the face of flood risks.[179]

Adoption of building codes that require anti-flooding fits to buildings is a rather low-cost proposition, but enforcement of these building codes can be an expensive undertaking for these local governments. Enforcing building codes requires hiring of compliance staff, which requires salary and benefit payments as well as the staffing costs around office and facilities needed for any hire made by a municipal government. FEMA argues that costs to builders will be small, with the new costs for flood prevention increasing costs of construction by 1.2-1.7 percent.[180] These costs, however, will likely be passed on to homeowners and renters, a consideration for policymakers concerned with housing affordability.

177 "What Is Stormwater Management and Why Is It Important?," EEC Environmental, 2021, Available Online: https://eecenvironmental.com/what-is-stormwater-management/

178 Ramakrishna, Saritha, "Climate Impacts Are Here Now, So Why Aren't Our Buildings Better Prepared?," Conservation Law Foundation, August 9, 2021, Available Online: https://www.clf.org/blog/climate-impacts-are-here-now-so-why-arent-our-buildings-better-prepared/

179 "Frequently Asked Questions About Building Science: Floods," Building Science, Risk Management, Emergency Managers, Federal Emergency Management Agency, September 17, 2020, Available Online: https://www.fema.gov/emergency-managers/risk-management/building-science/faq-flood

180 "Building Codes Save: A Nationwide Study," Federal Emergency Management Agency, November 2020, Available Online: https://www.fema.gov/sites/default/files/2020-11/fema_building-codes-save_study.pdf

Obtaining easements to use privately-owned land for temporary water retention and drainage.

Climate change impacts the frequency and severity of flooding, which will impact the need for easements for temporary water retention and drainage.[181] Often, private lands will be the best available sites for water retention and drainage during times of heavy flooding. An easement allows a government to use private property for a specific purpose such as water retention and drainage.

Private landowners are unlikely to donate their land for these purposes, however. Even using a heavy-handed tool like eminent domain will require fair compensatory payments from local governments, meaning costs for this strategy are unavoidable.

The cost of obtaining easements will vary depending on local economic conditions. Easements may be more difficult and costly to obtain in an expensive, densely-populated community where land values are high. A fact sheet from the West Central Ohio Land Conservancy reports nine major costs for setting up an easement: attorney fees, title search, title insurance, survey fees, recording fees, accountant fees, document preparation fees, fees to the land trust, and property appraisal fees.[182] These costs range from hundreds to thousands of dollars and may be split between the landowner and the local government seeking an easement. This does not include the main cost, which is the cost of purchasing the easement and paying the private property owner for the right to use her property for temporary water retention and drainage. These will depend on local economic conditions and individual negotiations.

The Ohio EPA provides a technical assistance manual for construction to handle stormwater runoff that notes the importance of easements in the stormwater runoff system.[183] Costs of ongoing stewardship of easements can be substantial, with a recent report by a Pennsylvania conservation group finding average annual stewardship costs to be $790 per easement, with a range from $430 to $1,500.[184]

Joining or improving compliance with the National Flood Insurance Program (NFIP).

The National Flood Insurance Program (NFIP) is a national insurance program to help reduce the economic impact of flooding throughout the United States.[185] As storm patterns intensify, new communities may be compelled to join the NFIP to mitigate risk around flooding. In particular, local government buildings may need to be insured in order to reduce risk of flooding and to receive compensation in the case of a flood.

181 Owley, Jessica. "Conservation easements at the climate change crossroads." Law & Contemp. Probs. 74 (2011): 199.

182 "Costs Associated with Setting Up an Easement and Filing for Federal Tax Incentives," West Central Ohio Land Conservancy, Available Online: https://www.wcolc.org/www/Pictures/Easement_04_2013.pdf

183 "Post-Construction Stormwater Management Practices," Technical Assistance, Ohio Environmental Protection Agency, Available Online: https://epa.ohio.gov/Portals/35/storm/technical_assistance/Ch2_Adapted%20for%20CGP%20changes.pdf

184 "Costs of Conservation Easement Stewardship," Guides, WeConservePA, Available Online: https://conservationtools.org/guides/86-costs-of-conservation-easement-stewardship

185 "Flood Insurance," Federal Emergency Management Agency, May 26, 2021, Available Online: https://www.fema.gov/flood-insurance

A network of about 60 insurance companies manage the NFIP. Flood insurance risks, like any kind of risk, vary by risk depending on a range of factors. Increased flooding can increase that risk, causing certain properties that were not previously required to take part in the NFIP to begin to take part in it, possibly leading to higher premiums for other communities.

New properties may need to participate in the NFIP. While properties are required to take part in the program if they are within a floodplain, increased risk of flooding may further compel properties to take part in the program, leading to increased danger to communities that do not take part. Increased compliance with the NFIP will make sure that flood risk is mitigated and that local governments will have funds available to pay for new facilities in the event that current facilities are damaged by floods. These funds could be crucial during a recovery effort.

A study conducted for FEMA estimated that the number of NFIP policies may increase by 80 percent by 2100 due to riverine and receding coastal shorelines.[186] The average cost for a property owner to buy into the NFIP is $700.[187] There is no fee for a community to join, though there could be compliance costs that communities will bear instead.

Implementing floodplain management beyond NFIP requirements, like the Association of State Floodplain Managers "No Adverse Impact" policy or FEMA NFIP Community Rating System (CRS).

Local governments are likely to face new flooding challenges in the face of increased rainfall and frequency of storms straining the local water system.[188] Increased storm frequency and intensity may push communities past the requirements for the National Flood Insurance Program (NFIP) toward more rigorous flood mitigation standards. The Association of State Floodplain Managers' "No Adverse Impact" policy is a strategy for floodplain management that runs the gamut from hazard identification and floodplain mapping to education and outreach, planning, regulations and development standards, mitigation, infrastructure, and emergency services, all of which have costs associated with them.[189]

FEMA's Community Rating System (CRS) is an incentive program that encourages community floodplain management practices that exceed the minimum requirements of the NFIP. It encourages management practices much like those of the No Adverse Impact program and has similar costs associated with it. A serious mapping project can be quite expensive, though. For instance, a mapping project to update FEMA floodplains in Charlotte in 1999 cost $1.4 million.[190]

186 "FEMA Climate Change Report," AECOM, Available Online: https://aecom.com/fema-climate-change-report/

187 Lankford, Kimberly, "How Much Does Flood Insurance Cost?," Kiplinger, October 2, 2015, Available Online: https://www.kiplinger.com/article/insurance/t028-c001-s003-how-much-flood-insurance-costs.html

188 Denchak, Melissa, "Flooding and Climate Change: Everything You Need to Know," Natural Resources Defense Council, April 10, 2019, Available Online: https://www.nrdc.org/stories/flooding-and-climate-change-everything-you-need-know

189 "No Adverse Impact: A Toolkit for Common Sense Floodplain Management," Association of State floodplain Managers, 2003, Available Online: https://s3-us-west-2.amazonaws.com/asfpm-library/FSC/NAI/ASFPM_No_Adverse_Impact_a_toolkit_for_common_sense_floodplain_management_2003.pdf

190 "No Adverse Impact Floodplain Management: Community Case Studies," No Adverse Impact, Association of Floodplain Managers, 2004, Available Online: https://www.msema.org/wp-content/uploads/2018/10/NAI_Case_Studies.pdf

Preserving floodplains as open space using any of several land use planning tools: develop a plan that targets hazard areas for acquisition, reuse, and preservation, a land banking program, use of transfer of development rights to keep floodplains vacant, easements to prevent development, or acquiring properties in the floodplain and turning them into open space.

Floodplains can be attractive locations for development. They are often nearby visually-appealing water features and can be adjacent to commercial, residential, or retail centers. Unfortunately, these areas can pose risk for property and ultimately human life, especially as climate change exacerbates current patterns of storm frequency and intensity. According to the United States EPA, preserving floodplains can help manage localized and riverine floods and provide a buffer to prevent loss of life and land.[191] Strategies such as park expansion planning, land banking, transfer of development rights, development prevention easements, and property acquisition are all viable strategies for preservation of floodplain space but also all strategies that will present costs to local governments.

Due to increased extreme weather and changes in sea levels, the nation's floodplains are expected to increase by 45 percent by 2100.[192] The main cost for floodplain preservation is the opportunity cost of development. For instance, a floodplain preservation program in St. Louis was found to have an annual opportunity cost of $17 million in undeveloped land, which itself would lead to losses in property tax revenue.[193]

Education and Awareness Programs

Increasing public outreach to encourage flood insurance purchase; educate residents in flood safety, flood mitigation, technical assistance availability, funding sources and best practices.

One tool for local governments to fight flooding is to educate residents on the impacts of floods so they understand the risks of foregoing flood insurance and have a general awareness of the types of coverage that are available to them as a homeowner or renter. Education can also help residents know how to prevent and deal with floods as they happen. Some communities have designed online courses for community members to learn more about local flooding.[194]

All of these tools will have costs associated with them. Public education programs, even the development of an online course, require resources for professional services and even some operational overhead. Providing technical assistance and help with best practices means paying staff to administer them. FENA provides resources for communities to educate the public on flood insurance.[195] But public outreach campaigns can take on a

191 "Manage Flood Risk," United States Environmental Protection Agency, Available Online: https://www.epa.gov/green-infrastructure/manage-flood-risk

192 "FEMA Climate Change Report," AECOM.

193 Kousky, Carolyn, and Margaret Walls. "Floodplain conservation as a flood mitigation strategy: Examining costs and benefits." Ecological Economics 104 (2014): 119-128.

194 Rothkrantz, Leon JM, and Siska Fitrianie. "Public Awareness and Education for Flooding Disasters." In Crisis Management-Theory and Practice. IntechOpen, 2018.

195 "Work With the National Flood Insurance Program," Flood Insurance, Federal Emergency Management Agency, January 8, 2021, Available Online: https://www.fema.gov/flood-insurance/work-with-nfip

range of different costs, from small website changes to multimillion-dollar programs like those used to promote vaccination.

Erosion

Infrastructure Projects

Relocating, demolishing or acquiring at-risk buildings (or other infrastructure).

More heavy and frequent rains brought on by climate change can lead to more erosion, which can put buildings and infrastructure at risk.[196] Erosion poses a different sort of risk to a state like Ohio than it does to a coastal state. Rather than worry about ocean coastlines, Ohio will face erosion on lakeshores and riversides that could impact the safety and stability of buildings as they exist now. Just as local governments work to rehabilitate or prevent the demise of neighborhoods driven by economic trends, they will likely be saddled with the responsibility of saving neighborhoods from erosion pressures as well.

FEMA recommends relocating, demolishing, or acquiring at-risk buildings as a strategy for mitigation of erosion risk.[197] Building relocation is an extremely expensive project, costing tens of thousands to hundreds of thousands of dollars.[198] According to one estimate, relocating a building can cost anywhere from $15,000 to $300,000.[199] Demolition and acquisition require similarly high costs. At-risk roads and supporting infrastructure are likely easier to address, but still present a challenge to local governments and will incur costs in the short-term.

Locating new utilities and critical facilities outside of susceptible areas.

Erosion caused by climate change is likely to impact existing urban water utilities.[200] In order to combat this problem, FEMA recommends locating new utilities and critical facilities outside of susceptible areas. However, erosion reduces the availability of land, which means that local governments are subject to the same pressures of supply and demand that any other organization trying to acquire land is subject to. This can make the relocation of facilities from susceptible areas especially difficult and expensive.[201] Erosion may cause real estate in lakefront and riverfront areas to go down in value.[202] As lakefront and riverfront properties become less desirable with the rise of erosion, remaining properties within a jurisdiction will increase in value, meaning location of new utilities and critical facilities will cost more than they would otherwise.

196 "Climate Adaptation and Erosion & Sedimentation," United States Environmental Protection Agency, Available Online: https://www.epa.gov/arc-x/climate-adaptation-and-erosion-sedimentation

197 "Mitigation Ideas: A Resource for Reducing Risk to Natural Hazards," Federal Emergency Management Agency, January 2013, Available Online: https://www.fema.gov/sites/default/files/2020-06/fema-mitigation-ideas_02-13-2013.pdf

198 "6 Factors Impacting The Cost To Move or Relocate A Building," DeVooght House Lifters, October 22, 2020, Available Online: https://www.devooghthouselifters.com/cost-to-move-or-relocate-a-building/

199 "6 Factors Impacting The Cost To Move or Relocate A Building," DeVooght House Lifters.

200 Cromwell, John E., Joel B. Smith, and Robert S. Raucher, "Implications of climate change for urban water utilities." Washington, DC: Association of Metropolitan Water Agencies, 2007.

201 "Mitigation Ideas," Federal Emergency Management Agency.

202 Below, Scott, Eli Beracha, and Hilla Skiba. "Land erosion and coastal home values." Journal of Real Estate Research 37, no. 4 (2015): 499-536.

Even if local governments were not previously planning on relocating utilities and critical facilities, increased risk of erosion due to climate change may cause them to reconsider this strategy. Relocation could mean anything from acquiring and renovating low-cost buildings to constructing completely new facilities, all of which would have costs associated with them. Erosion is creating a double problem for local governments: making the cost of property higher while it forces them to purchase new property. Especially expensive would be new water treatment plants, whether they be waste water treatment or drinking water treatment plants. One estimate says that water lines cost $50 to $250 per linear foot to relocate.[203]

Implementing site and building design standards, such as constructing open foundation systems or deep foundations.

Wetter winters and more sudden, heavy downpours will increase the importance of designing sites and buildings to direct rainwater and meltwater away from structures and infrastructure.[204] While traditional foundations require water to flow around the foundation, open foundation designs leave room underneath a building for water to flow freely. An open foundation makes the building more integrated with the water system around it. A deep foundation is one that penetrates deep into the earth, creating more of an anchor for the building and thus allowing for a more stable foundation, while also creating a way to stave off erosion.

Costs associated with implementing site and building design standards start with creating the standards and adopting them, which cost staff time. Implementation of standards also means education and enforcement, both of which require new training and staff. The largest cost for local governments, however, may come from compliance with their own standards after they have been put in place. Open and deep foundations require specialized training and different or more materials than traditional foundations do. This could drive up the costs of construction and therefore pose new costs for local governments.

The USDA puts forth six general principles for effective erosion control: reducing erosive forces and increasing resisting forces, applying good erosion control for good sediment control, modifying topography or grade, limiting soil exposure, keeping runoff velocities low, and inspecting and maintaining treatments.[205]

203 "How Much Does Water Main Installation & Replacement Cost?," HomeAdvisor, Available Online: https://www.homeadvisor.com/cost/plumbing/install-a-water-main/

204 "Climate change impact on buildings and constructions," Climate Change Adaptation, Available Online: https://en.klimatilpasning.dk/sectors/buildings/climate-change-impact-on-buildings/

205 Rivas, Todd. Erosion control treatment selection guide. No. 0677 1203—SDTDC. 2006.

An estimate by the state of New York of erosion control practices put the price at $5,000, but the cost could vary depending on the site and risks associated with it.[206]

Stabilizing susceptible slopes, stream banks, and shorelines using grading techniques, planting vegetation, terracing hillsides, installing boulders, riprap or geotextile fabric, or bioengineering bank stabilization techniques.

According to the United States EPA, more intense and frequent rains will impact both stream ecosystem health and water quality.[207] The United States Department of Energy cites erosion control methods during construction, vegetation planting on slopes, terracing, retaining walls, bioengineering, and dune preservation to stabilize shorelines.[208]

Local governments have some tools they can use to stabilize slopes, stream banks, and shorelines. They also have tools to reduce the chances that erosion will occur in the first place. Grading techniques are engineering techniques and vegetative practices that provide surface drainage and control erosion and sedimentation while reshaping and stabilizing the ground surface.[209] Terracing hillsides prevents erosion by shortening a long slope into a series of shorter, more level steps. This allows heavy rains to soak into the soil rather than run off and cause erosion.[210] Boulders can be used to install what is called "riprap," that is a line of boulders that hold soil back and prevent erosion. Riprap can cost from $35 to $60 per square yard.[211]

Geotextile fabrics are large rolls of fabric that can be laid out on soil to keep it in place and hamper erosion. Bioengineering-backed stabilization techniques draw on horticultural practices to build plant communities on shorelines to prevent erosion. All of these strategies provide options for local governments looking to prevent erosion, and each of them presents local governments with one type of cost or another.

Prohibiting removal of vegetation from dunes and slopes.

Vegetation on dunes and slopes can hold soil in place and prevent erosion. Removal of vegetation could lead to more landslides, something that climate change can also exacerbate.[212] The state of Michigan has promulgated best management practices for sand

206 Lake, Donald W., "Cost Analysis of Erosion and Sediment Control Practices," New York State Standards and Specifications for Erosion and Sediment Control, November 2016, Available Online: https://www.dec.ny.gov/docs/water_pdf/appendixcaesedcp.pdf

207 "Climate Adaptation and Erosion & Sedimentation," United States Environmental Protection Agency.

208 "Erosion Control for Slopes, Stream Banks, and Dunes," Solution Center Home, Building America, Building Technologies Office, Office of Energy Efficiency & Renewable Energy, United States Department of Energy, September 30, 2020. Available Online: https://basc.pnnl.gov/resource-guides/erosion-control-slopes-stream-banks-and-dunes

209 "Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas: A Guide for Planners, Designers, and Municipal Officials," Franklin, Hampden, Hampshire Conservation Districts, May 2003, Available Online: https://megamanual.geosyntec.com/npsmanual/source/ES%20Control%20Guidelines%20for%20Urban%20and%20Suburban%20Areas.pdf

210 "Backyard Conservation – Terracing," United States Department of Agriculture, Natural Resources Conservation Service, 2017, Available Online: https://web.archive.org/web/20130723161437/http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/newsroom/features/?&cid=nrcs143_023575

211 Rodriguez, Juan, "Costs and Installation Tips When Building a Riprap Barrier," The Spruce, August 1, 2021. Available Online: https://www.thespruce.com/costs-and-installation-tips-when-building-a-riprap-844741

212 Palmer, Jane, "A Slippery Slope: Could Climate Change Lead to More Landslides?," Eos, November 23, 2020, Available Online: https://eos.org/features/a-slippery-slope-could-climate-change-lead-to-more-landslides

dunes that mention the importance of minimizing vegetation removal around dunes.[213] Permits for removal of trees cost from $250 to $600 and collection of the fees poses an additional operational cost to the state.[214]

Prohibiting removal of vegetation comes with its own costs, though. Rules must be created and passed, both taking staff time to accomplish. Local government staffers need to educate the public on new rules, which can take staff time and resources to do. Also, local governments that want residents and businesses to follow their rules will need to allocate resources towards enforcement.

Local Planning and Regulations

Identifying, mapping, or tracking erosion hazard areas.

Local governments are likely the only stakeholders in their community with a direct incentive to identify, map, and track erosion hazard areas. These undertakings will require staffing, equipment, and administrative overhead in order to be carried out successfully. Staff will be needed to visit susceptible areas to test for erosion and monitor those locations over time. Local governments will also require maps so they can understand geographic trends in erosion, but also so the public understands the trajectory of erosion in the community and can make choices for their own safety that match the realities of the threat. This could also have impacts on property values, which could impact municipal revenues down the line. Addressing these issues might make this sort of program difficult to implement, but important nonetheless.

The United States Federal Government is tracking erosion areas and how they will be impacted by climate change.[215] For years, states like Massachusetts have convened commissions on erosion hazard areas.[216] Costs for identification, mapping, and tracking of erosion hazard areas can be hard to determine, but a similar study, an ecological impact assessment, has been cited at 750 to 1200 British pounds, or $1,000-$1,600 per site study.[217]

Developing and enforcing an erosion management plan.

Climate change is expected to increase the frequency and intensity of storms, leading to higher erosion and more sediment flowing into rivers, lakes, and streams.[218]

213 "Sand Dune Stabilization," Water Resources Division, March 9, 2017, Available Online: https://www.michigan.gov/-/media/Project/Websites/egle/Documents/Programs/WRD/NPS/Tech/BMP/bmp-sand-dune-stabilization.pdf?rev=59ea081786444a82b24a791ddd07cdc0

214 "Critical Dune Area Permit Fees," Michigan Department of Environment, Great Lakes, and Energy, 2021, Available Online: https://www.michigan.gov/egle/about/organization/water-resources/sand-dunes/critical-dune-area-permit-fees

215 "Coastal Erosion," U.S. Climate Resilience Toolkit, April 1, 2021, Available Online: https://toolkit.climate.gov/topics/coastal-flood-risk/coastal-erosion

216 "Report of the Massachusetts Coastal Erosion Commission," Volume 1: Findings and Recommendations, December 2015, Available Online: https://www.mass.gov/files/documents/2016/12/sd/cec-final-report-dec2015-complete.pdf

217 "Costs of an Ecological Impact Assessment," Ecology by Design, 2020, Available Online: https://www.ecologybydesign.co.uk/ecology-resources/costs-of-an-ecological-impact-assessment

218 "Climate Adaptation and Erosion & Sedimentation," United States Environmental Protection Agency.

The United States EPA provides an erosion and sediment control model ordinance for communities interested in building erosion management plans into their city building procedures.[219]

Erosion management plans can be effective tools for building community-wide strategies for reducing erosion. While erosion management plans often happen at the property level and can be handled by private property owners in those cases, local governments that may be affected strongly by erosion may develop community-wide erosion management plans that help the entire community plan how they will address erosion. In Apex, North Carolina, application for approval of a soil erosion plan costs $500, which can be a starting point for communities trying to estimate the cost of developing and enforcing their own erosion management plans.[220]

An erosion management plan will have many of the same costs that come with developing any other plan. Engineers and land surveyors will likely need to be hired to assess erosion throughout the community and provide a baseline for the management plan. Environmental consultants, planners, and economists may all have roles to play in the development and implementation of these plans. Other costs associated with designing and implementing an erosion management plan might include equipment, use of public facilities, operations, and unexpected costs that come with use of land. A well-designed erosion management plan will also need to be enforced, which may have additional costs. There may also be costs associated with getting private sector interests and other members of the community on board with the plan and building a community consensus around its execution.

Developing site and building design standards.

Climate change is coming to impact the way buildings are built, with one commentator in Architecture Magazine calling it "the fundamental design problem of our time."[221] With half the carbon dioxide emissions in the United States coming from buildings, pressure is mounting for better site and building design standards that take this problem into account. The American Institute of Architects provides a range of resources for architects looking to design buildings that can handle changes to the climate.[222]

The United States EPA has provided a model ordinance for local governments interested in incorporating erosion control into the construction process.[223] It requires anyone who wants a site development permit for land-disturbing activity that would require the uncovering of a large amount of land to gain the approval of an erosion and sediment control plan by a local agency.

219 "Erosion and Sediment Control Model Ordinance," Environmental Protection Agency, Available Online: https://www.epa.gov/sites/default/files/2015-12/documents/e-s_model_ordinance1.pdf

220 "Soil Erosion & Sedimentation Control," Apex, NC, Available Online: https://www.apexnc.org/269/Soil-Erosion-Sedimentation-Control

221 Cramer, Ned, "The Climate Is Changing. So Must Architecture.," Architect Magazine, October 4, 2017, Available Online: https://www.architectmagazine.com/design/editorial/the-climate-is-changing-so-must-architecture_o

222 "Climate change adaptation design resources," American Institute of Architects, 2021, Available Online: https://www.aia.org/pages/77741-climate-change-adaptation-design-resources:56

223 "Erosion and Sediment Control Model Ordinance," Environmental Protection Agency, Available Online: https://www.epa.gov/sites/default/files/2015-12/documents/e-s_model_ordinance1.pdf

Like any standard that is put in place by a local government, site and building design standards around erosion would require some costs for local governments that establish them. New standards would need to be designed by staff. Construction companies would need to be informed of the new rules and the rules would have to be listed publicly. Most crucial of all, the new standards would need to be enforced. The cost to develop standards can range considerably between communities, with one quote from 2013 estimating the cost for developing a policy at $5,000.[224]

Many of these costs would incur in the form of staff time, informational materials, web hosting, hosting of public events for input or for education on the new standards, and enforcement. Additionally, if local governments are establishing and enforcing new standards, they will be subject to those standards as well, which may create new costs for local governments building new government buildings within their municipal boundaries.

Education and Awareness Programs

Increasing awareness by disclosing location of high-risk areas to current and future property owners; offer mitigation technique information.

High-risk erosion can impact people's safety, health, and finances. A research article published last year in the Proceedings of the National Academy of Sciences of the United States of America estimates climate change will speed global water erosion by 30 to 66 percent.[225] Residents living in high-risk areas have the potential to be harmed or lose their home if erosion grows more rapid with changing climate. Future residents may also make different decisions about where they would like to live if they have full information about the risks involved in living in a neighborhood that is at a high risk for erosion. Local governments have reason to increase awareness about the risk of living in these areas and provide mitigation technique information to people who decide to live in these areas. The Federal Emergency Management Agency suggests notifying property owners in high-risk areas as a best practice for increasing awareness of erosion hazards.[226]

Some researchers have found that residents of Gulf States are more aware of erosion risks than other states, suggesting understanding of erosion risks might be more limited in Ohio than in other states.[227] Education costs include materials for education but most crucially, staff salaries to support education efforts. Education and awareness programs can run a range of costs, but one estimate for the cost of a typical social media campaign from a few years ago was $4,000 to $7,000.[228]

224 Kusserow, Richard P., "Developing Compliance Policies and Procedures," Strategic Management Services, September 2013, Available Online: https://www.compliance.com/resources/developing-compliance-policies-and-procedures/

225 Borrelli, Pasquale et al, "Land use and climate change impacts on global soil erosion by water (2015-2070)." Proceedings of the National Academy of Sciences 117, no. 36 (2020): 21994-22001.

226 "Mitigation Ideas," Federal Emergency Management Agency.

227 Huang, Jialing, and Kevin Ells. "Risk Here vs. Risk There: Intention to Seek Information About Gulf Coastal Erosion." Environmental Communication 15, no. 3 (2021): 386-400.

228 Shiotsu, Yoshitaka, "How Much Does it Cost to Run a Social Media Campaign?," Upwork, April 20, 2018, Available Online: https://www.upwork.com/resources/social-media-campaign-cost

Local governments also may be interested in offering erosion mitigation technique information to residents. While this could be as simple as pamphlets or online materials, it could also come in the form of technical assistance, which would cost more with staff salaries or wages as a consideration.

Other Extreme Weather

Structure and Infrastructure Projects

Burying overhead power lines or installing systems that allow small sections of power lines to fail rather than the complete system.

Grid reliability is a key concern in a time when heavy snows are becoming more frequent and intense. The 2020-2021 snowstorms in Texas show what happens to a grid that is not prepared for snowstorms and how it can impact public safety and quality of life. Snowstorms are a regular occurence in Ohio, but an increase in snowstorms could easily lead to grid failure that municipalities and residents are unprepared for.

Trees are the leading cause of service interruption for most electric distribution utilities.[229] FEMA recommends burying power lines as a strategy for reducing power disruptions.[230] Burying power lines is an expensive proposition, however, costing $1 million per mile according to one estimate. However, burying power lines could provide aesthetic benefits that far outweigh the costs associated with burying the lines, even in an urban setting.[231]

Another way to prevent large-scale failures is to increase the sections of power line that need to fail in order for the entire system to fail. By making it more difficult for a small line drop to create a grid-wide failure, it will make the grid more resilient and more robust against widespread increases in heavy snows. This practice along with burying provide two possible options for communities to increase grid reliability, but will come at a cost to ratepayers and local governments.

229 Finch, Kenneth E., "How Trees Cause Outages - Understanding Tree Caused Outages: The Research," ECI Consulting, Available Online: https://www.eci-consulting.com/wp-content/uploads/2017/10/Understanding-Tree-Caused-Outages.pdf

230 "From Overhead to Underground: It Pays to Bury Power Lines," Federal Emergency Management Agency, Available Online: https://www.hsdl.org/?view&did=14253

231 Navrud, Ståle et al, "Valuing the social benefits of avoiding landscape degradation from overhead power transmission lines: Do underground cables pass the benefit–cost test?." Landscape research 33, no. 3 (2008): 281-296.

Appendix C: Ranges of Likely Values for Each Variable Used in Simulation of Midcentury Cooling Costs

Variable	Low	High
Percentage increase in costs for percentage increase in temperature[231]	1%	3%
Percentage of utility costs attributable to cooling costs[232]	22%	64%
Total national utility cost[233]	$10 billion	$12 billion
Increase in temperature due to climate change[234]	1 degree Fahrenheit	6 degrees Fahrenheit

232 Wahl, Jen, "Does changing your thermostat a degree or 2 really affect your wallet?," 12 News, September 18, 2018, Available Online: https://www.12news.com/article/news/local/valley/does-changing-your-thermostat-a-degree-or-2-really-affect-your-wallet/75-595785810

233 "What percentage of your electric bill is heating and cooling?," FindAnyAnswer, April 9, 2020, Available Online: https://findanyanswer.com/what-percentage-of-your-electric-bill-is-heating-and-cooling

234 "Local Governments: An Overview of Energy Use and Energy Efficiency Opportunities," Energy Star, Available Online: https://www.energystar.gov/sites/default/files/buildings/tools/SPP%20Sales%20Flyer%20for%20Local%20Government.pdf

235 "Climate Impact Map," Climate Impact Lab, 2022, Available Online: https://impactlab.org/map/#usmeas=absolute&usyear=1981-2010&gmeas=absolute&gyear=1986-2005&usrcp=rcp45&usprob=0.95

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