Toxic Tides

Mapping disproportionate risks at flood-prone hazardous sites

Modeled visualization of a 100-year coastal flood at a fossil fuel terminal in Mobile, Alabama, in 2100 if heat-trapping pollution grows unchecked (RCP 8.5). Image produced using FloodVision technology.

CLIMATE CENTRAL

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Introduction

Along America's coastlines are some of the most storied histories of America itself, from Indigenous communities living off the land and the bounty of the sea to the modern-day societies that have blossomed in the wake of industrial development.

These coastal communities now find themselves at the forefront of rising sea levels and stronger storms, both driven by heat-trapping pollution and rising temperatures. Just last year, Americans endured 27 disasters that each led to at least $1 billion in estimated losses. At the same time, 2024 set another record as the world's warmest year.

Potentially hazardous sites like fossil fuel ports, refineries, chemical plants, sewage treatment facilities, and other heavy industries can often be found along the coast, nestled among communities that predate them or have grown around them over time. When disaster strikes, that proximity can lead to exposure to toxic substances, which can result in environmental and public health disasters and leave lingering problems long after floodwaters recede.

Now, a new study co-authored by environmental and climate scientists at the University of California, Nanjing University, and Climate Central and published in the journal Nature Communications finds that historically underserved communities are more likely to live near hazardous sites at risk from worsening coastal floods.

"Flooding from sea level rise is dangerous on its own — but when facilities with hazardous materials are in the path of those floodwaters, the danger multiplies," says the paper's lead author, Lara Cushing, an associate professor at UCLA's Fielding School of Public Health. "This analysis makes it clear that these projected dangers are falling disproportionately on poorer communities and communities that have faced discrimination, and therefore often lack the resources to prepare for, retreat, or recover from exposure to toxic floodwaters."

New resources from Climate Central, such as the Toxic Tides mapping tool, allow users to explore data from the recently published study and pinpoint specific sites and communities, down to the streetscape or doorstep, that face increasing flood risks.

Key Findings

- **5,500 hazardous facilities** along America's coastlines are expected to be at risk of flooding during a 100-year coastal flood by the end of this century if heat-trapping pollution grows unchecked (RCP 8.5).
    - Cuts to pollution in line with pledged commitments (RCP 4.5) would reduce the number of at-risk sites by **362 (7%)**.
    - **More than two-thirds** of the facilities at risk by 2100 will be at risk of inundation during 100-year coastal flood events within the next 25 years, in either pollution scenario.
- Neighborhoods with higher proportions of residents who are renters, non-voters, living in poverty, don't have a vehicle, don't speak English well, identify as Hispanic, or are over the age of 65 are **15-41% more likely** to have an at-risk hazardous site within 1 kilometer (.62 miles).
- The 47,646 facilities analyzed were collated from four different public data sources and one proprietary source, and include industrial facilities, fossil fuel and nuclear power plants, CAFOs, sewage treatment facilities, landfills and incinerators, contaminated cleanup sites (including Superfund sites), refineries, fossil fuel ports and terminals, oil and gas wells, and other facilities that treat or dispose of hazardous waste.
- The following will be at risk of flooding during a 100-year coastal flood by the end of the century under a very high emissions scenario:
    - Over **one-fifth** of coastal sewage treatment facilities, refineries, and formerly used defense sites;
    - About **one-third** of coastal power plants;
    - Over **40%** of coastal fossil fuel ports and terminals.
- **Almost 80%** of the 5,500 at-risk facilities are found in just **seven states**: Louisiana, Florida, New Jersey, Texas, California, New York, and Massachusetts.

Facility Type	Total number of facilities analyzed	Number of facilities at risk in 2050		Number of facilities at risk in 2100	
		If pledged commitments to reduce heat-trapping pollution are met (RCP 4.5)	If heat-trapping pollution grows unchecked (RCP 8.5)	If pledged commitments to reduce heat-trapping pollution are met (RCP 4.5)	If heat-trapping pollution grows unchecked (RCP 8.5)
Power plants	443	84	85	125	134
Animal operations	1,148	87	88	111	115
Sewage treatment	2,582	379	384	525	564
Hazardous Waste	515	44	46	68	74
Industrial Facilities (TRI)	15,222	1,049	1,073	1,679	1,870
Landfills & Incinerators	948	50	51	79	90
Cleanup Sites	604	64	66	100	111
Refineries	67	9	9	14	16
Ports & Terminals	663	196	199	275	293
Oil & Gas Wells	24,095	1,592	1,597	1,895	1,944
Formerly Used Defense Sites	1,359	186	190	267	289
Total	*47,646*	*3,740*	*3,788*	*5,138*	*5,500*

Table 1. Number and type of hazardous facilities at risk of inundation during a 100-year coastal flood in the United States by year and pollution scenario. For state, county, and facility-level data, visit the Toxic Tides mapping tools.

Mapping Local Data with the Toxic Tides Tool

With over 5,000 at-risk coastal sites across dozens of unique American communities, the data points included in this report are just a starting point for journalists, researchers, decision-makers, and residents to explore what's at risk in their own neighborhoods. Climate Central's Toxic Tides maps allow users to view risk on a facility-by-facility basis or aggregated by county and state, download data and maps, and explore different scenarios and metrics.

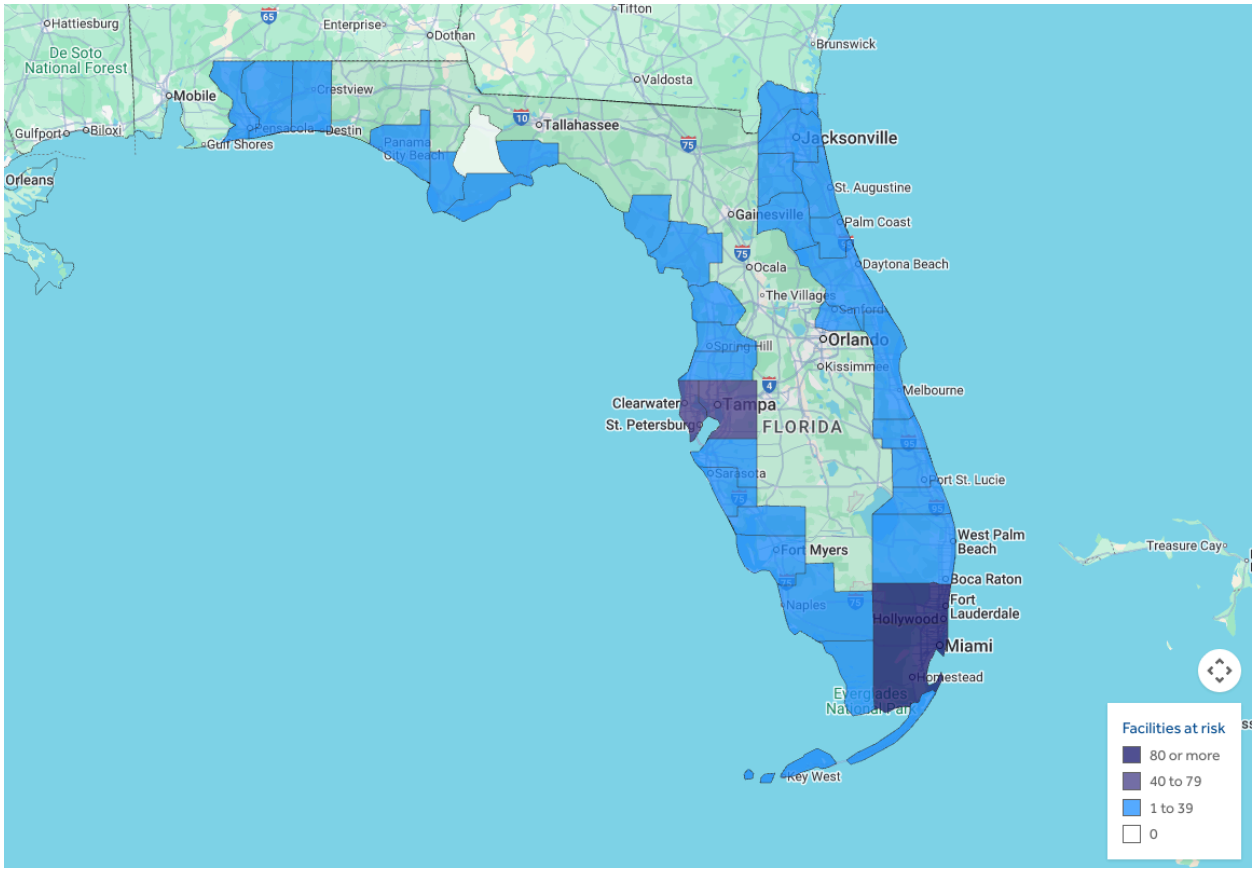

Figure 1. Counties in Florida color-coded by the number of hazardous facilities at risk of flooding during a 100-year event in 2100 if heat-trapping pollution grows unchecked. Darker blue indicates more at-risk facilities. Access interactive maps like this one using the Toxic Tides tool.

A disproportionate share of risk

All of the data compiled as part of this study represent much more than geocoded points and demographic information. These numbers translate to real lives.

That might be families from St. James Parish, Louisiana, in what some know as Cancer Alley, who have nowhere else to go in the face of rising floodwaters.

A family in Florida that has to deal with feces seeping up from the floors during major hurricanes.

Or the many people living in Mid-Atlantic metropolitan areas who can't make it to work or the doctor because the local gas station is completely out of fuel.

“We have to confront these NaTech disasters and really raise the alarm and educate folks about places that are vulnerable to these types of situations,” says University of Maryland-College Park School of Public Health Professor Sacoby Wilson. Wilson was not involved in the recently published study.

NaTech, short for “natural-technological,” refers to disasters that combine elements of both natural and technological disasters. For example, Hurricane Katrina was a NaTech disaster, in that the devastating storm triggered toxic impacts from industrial incidents like oil spills and excess emissions, leading to widespread pollution exacerbated by flooding. The Fukushima nuclear accident of 2011 is another example.

Compared to other coastal neighborhoods, neighborhoods with one or more at-risk hazardous facilities nearby have higher proportions of renters, households living in poverty, residents identifying as Hispanic or Black, households that don’t have anyone who speaks English well, households without a vehicle, single-parent households, adults over the age of 65, and non-voters.

The analysis also found that certain types of hazardous facilities tend to disproportionately burden different vulnerable groups of residents living nearby. For example, power plants, clean-up sites, fossil fuel ports and terminals, and other industrial sites that are at-risk from future sea level rise-driven coastal flooding are often located in and around neighborhoods with higher percentages of renters and non-voters, as well as households without a personal vehicle, living in poverty, and who don’t speak English very well. In contrast, at-risk oil and gas wells, hazardous waste sites, landfills, and formerly used defense sites are disproportionately located near Native American communities.

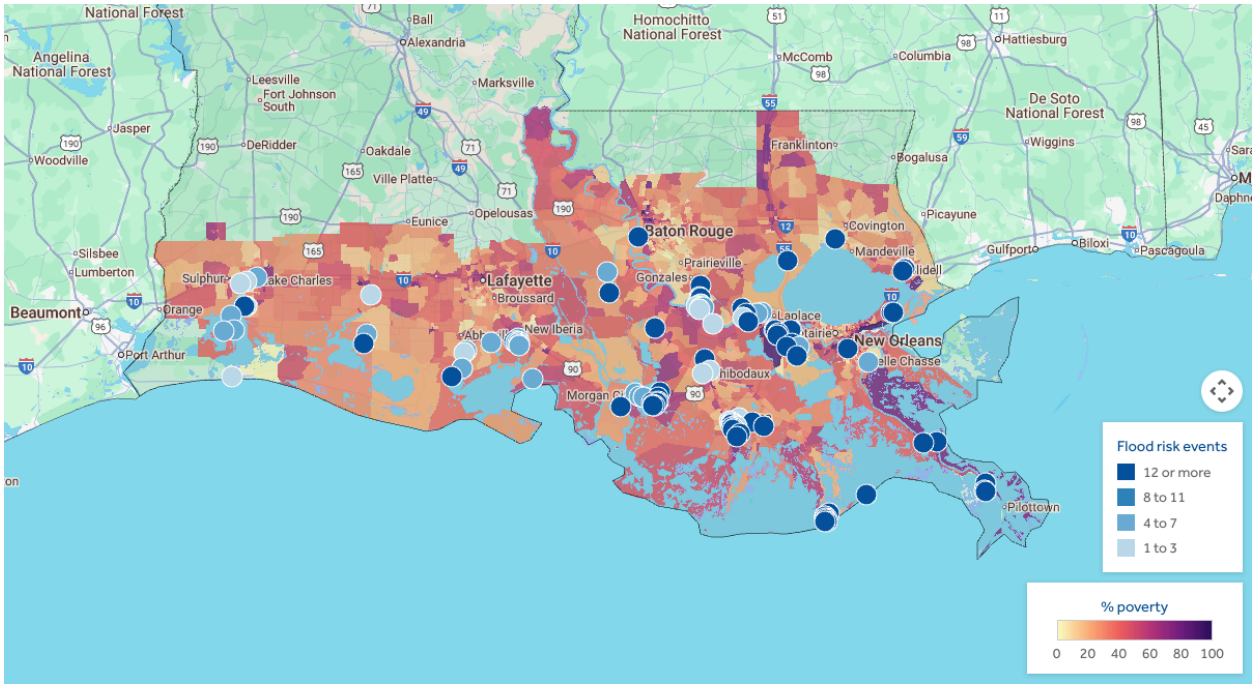

Figure 2. Hazardous facilities at risk of one or more floods a year by 2100 if heat-trapping pollution grows unchecked in Louisiana (darker blue indicates higher levels of risk). Regions are color-coded by the percentage of the total population that is below twice the federal poverty line (yellow indicates less poverty, while purple indicates more poverty). Access interactive maps like this one using the Toxic Tides tool.

	No at-risk hazardous facilities nearby	At least one at-risk hazardous facility nearby
% non-voters	26.2%	29.1%
% poverty	25.6%	29.3%
% renters	34.6%	48.3%
% people of color	44.8%	47.2%
% Hispanic	11.3%	12.6%
% Black	4.3%	5.3%
% Asian & Pacific Islander	2.5%	2.3%
% Native American	0.0%	0.0%
% other people of color	1.6%	1.5%
% linguistic isolation	2.6%	3.6%
% without a vehicle	5.6%	10.4%
% single-parent household	16.6%	16.9%
% over 65	23.5%	26.2%
% under 18	20.1%	19.3%

Table 2. Average (median) characteristics of coastal neighborhoods with and without at least one hazardous facility at risk of flooding during a 100-year event in 2100 if heat-trapping pollution grows unchecked within a kilometer (0.62 miles).

Health hazards from contaminated floodwaters

When people are exposed to floodwaters tainted by hazardous waste — whether sewage from local wastewater treatment facilities or hydrocarbons and heavy metals from impacted refineries or fossil fuel storage facilities — the health impacts can be wide-ranging and far-reaching.

“After the waters recede, there can be leftover materials in people’s homes: microbes, viruses,” says Wilson, emphasizing impacts from flood events that hit sewage plants or combined sewer overflow systems. “People can still be exposed.”

While sewage releases and bacterial contamination often cause the most acute public health threats in the wake of these disasters, other hazardous substances like toxic chemicals, heavy metals, and hydrocarbons from fossil fuel industries can also present serious health and environmental concerns. For example, exposure to oil spills has been linked to a variety of long-term health issues, such as heart problems, among clean-up workers. Meanwhile, the excess release of air pollution during catastrophic events like Hurricane Katrina can expose people to heavy metals and hazardous chemicals, which in turn can cause a variety of health conditions from respiratory issues to skin problems and worse.

In Texas, companies reported 95 incidents in the wake of Hurricane Harvey — another NaTech disaster — that resulted in the release of more than 10 million pounds of excess air contaminants. Meanwhile, previous studies have shown that under-resourced communities make up half of the people who live close to sites handling hazardous materials or waste.

“As sea level encroaches upon the footprint of these operations, the risk of a safety event at a facility increases, which means the risk of an adverse event for the local population increases,” says Wilson. “We’ve got to have more protections for the public.”

As climate change continues to threaten the lives and livelihoods of coastal communities, addressing these overlapping risks of rising tides and toxic threats is paramount to public health. Cleaning up after a flood is already challenging, but the lingering pollution of floodwaters containing hazardous waste and chemicals can present an additional set of problems.

A rise in resilience

While the new study looks ahead to impacts expected in 2050 and 2100, some sites are already experiencing the impact of rising tides. U.S. communities today are seeing coastal floods occur three times more frequently than they did just three decades ago. And areas along the Gulf Coast are contending not only with accelerating rates of sea level rise and storm surges that are among the highest on the globe, but also localized geological impacts, like subsidence, that lead to sinking land.

“We’re getting communities now flooding 20 to 25 days a year or more from just strong onshore winds. You don’t even need a hurricane,” says Galveston’s “Hurricane Hal” Needham, an extreme weather and disaster scientist who did not work on the recently published study.

When Needham moved to the Gulf Coast 17 years ago, there was no database for local coastal flooding, he says. So he started one that he continues today.

Why does that matter? Because localizing data gives a real look at what’s actually happening in a particular community or along a specific street, says Needham. When risks are understood better, communities can prepare and respond better.

“When you start with data, you’re starting to hone in on where these hazards happen, where are they most severe, and really, more importantly, once you build out a comprehensive flood history for a community, you can run statistics and get an idea of how often this building would flood or how often this refinery would flood or what’s the 100-year flood level,” says Needham. “Typically speaking, what I generally find is the data suggest that the flood levels are actually higher in most places than the FEMA flood maps.”

Whether the solution involves relocating certain vulnerable infrastructure to higher ground, rebuilding in new ways, or learning how to live with more and more water, the work should always be informed by good data.

Needham said he’s seen recent instances of success with mobile flood barriers, which are essentially massive, movable fences that are light enough for a team of people to deploy relatively quickly, but stable enough to keep out several feet of water. During Hurricane Milton, Tampa General Hospital used the barriers to fight floodwaters and continued caring for patients.

“That’s a pretty neat technology, and that’s the kind of thing I think we’ll be seeing more of with sea level rise and populations in flood-prone areas,” Needham says. “We’re going to need to be more creative moving forward.”

Figure 3. Mobile flood barriers at Tampa General Hospital. Photo courtesy of “Hurricane” Hal Needham.

While those mobile barriers might be better to protect a hospital’s footprint rather than an entire community, larger-scale solutions, like the proposed $20 million Coastal Spine Project that would protect a large swath of the upper Texas coast, including Galveston, are also possible.

In the meantime, Needham said he’s seen some creative building solutions that go beyond simply relocating or elevating buildings and vulnerable infrastructure. Dry-floodproofing and wet-floodproofing buildings by using better sealing materials or designing structures in a way that parts can get wet without being damaged (e.g., building the first floor with only concrete and steel instead of wood and drywall) can allow structures to remain in flood-prone areas. Then there are buildings with floors that can be raised with a pulley system to keep objects high and dry, and even buoyant foundations that have seemingly gained more traction in Central America and Asia, sometimes known as “amphibious architecture.”

This analysis offers a starting point for decision-makers and researchers aiming to understand and prepare for future flood risks to hazardous facilities and vulnerable communities in coastal areas.

“It all starts with having a proper assessment and projection of what can happen,” Needham says. “We can’t just keep doing things the way they’ve always been done.”

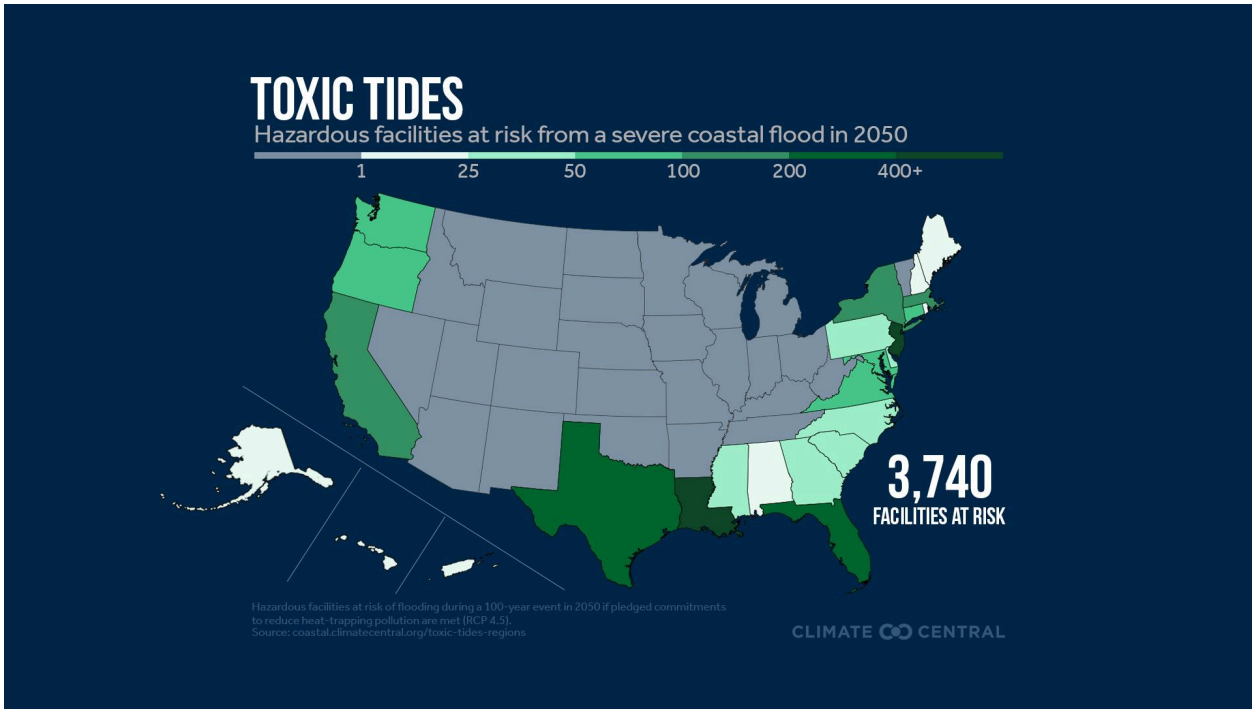

Figure 4. States color-coded by the number of hazardous facilities at risk of flooding during a 100-year event in 2050 if pledged commitments to reduce heat-trapping pollution are met. Darker green indicates more at-risk facilities.

Conclusion

If heat-trapping pollution continues to grow unchecked, 3,788 hazardous facilities in communities along America’s coastlines would endure floodwaters during a 100-year event by mid-century. By 2100, that number grows to over 11% of all facilities examined, with 5,500 hazardous facilities expected to flood during a 100-year coastal flood.

Unfortunately, the amount of sea level rise communities can expect through 2050, when today’s toddlers will be settling into the workforce, is essentially locked in by past pollution. But our climate choices matter in the long run: meeting pledged commitments to reduce heat-trapping pollution would reduce the number of sites at risk by the end of the century from 5,500 to 5,138 — a roughly 7% reduction.

Protecting public health will require adaptation as well as reducing pollution. The findings also underscore the need for continued disaster planning that truly accounts

for the overlapping environmental, industrial, and public health risks related to sea level rise impacts on hazardous sites.

According to Wilson, having a tool that shows the disproportionate risks from sea level rise and coastal flooding is crucial. “I think it’s very important to be able to visualize where you have these risks for hazardous sites.”

Methodology

Methods were co-developed with an advisory committee of community advocates and public health leaders.

Data on hazardous facilities used in this analysis are from the U.S. Environmental Protection Agency’s (EPA) Facility Registry Service (FRS), the U.S. Energy Information Administration’s (EIA) Energy Atlas (no longer publicly accessible), U.S. Army Corp of Engineers’ (USACE) Waterborne Commerce Statistics Center and Formerly Used Defense Sites database, and a proprietary dataset of active oil and gas production and stimulation wells from Enverus. Facilities were considered coastal and included in this analysis if they were in a county or county-equivalent with any land less than 18 meters above the high tide line.

Projected coastal flood heights were determined using sea level rise projections from Kopp et al. 2014, coastal flood modelling methods from Tebaldi et al. 2012, and updated tide station measurements from NOAA. The projected flood heights do not take into account the increasing intensity of storms driven by climate change.

To calculate what facilities will be at risk from a given flood level, lidar-derived elevation data provided by NOAA and levee data from FEMA’s Midterm Levee Inventory (2013) were used. This data determined which facilities are below the projected water level and hydrologically connected to the ocean. This approach, commonly known as bathtub modeling, takes into account whether a low-lying area is protected by higher ground or coastal protections, but does not account for wind, waves, or the inland attenuation of flood height from water flow friction. This analysis only considers coastal flooding — when the ocean rises, causing water to flow out over the land — and does not consider inland flooding.

Demographic and socioeconomic measures were compiled at the census block group level from the U.S. Census Bureau’s American Community Survey 2015–2019 five-year estimates, Catalist’s National Database’s voter turnout data from the 2016 and 2020 general elections, and the White House Council on Environmental Quality’s Climate and Economic Justice Screening Tool (no longer available from the federal government). Relationships between these indicators and proximity to at-risk sites

were statistically analyzed using descriptive statistics, regression models, and concentration curves and indices.

For more details on the methodology, see the peer-reviewed paper.

About Climate Central

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