CLIMATE CENTRAL

PICTURING OUR FUTURE

Cities face unprecedented threats from multi-century sea level rise

Today's climate and energy choices shape tomorrow's shorelines

New Climate Central research shows that under the current emissions pathway leading toward 3°C global warming, about 50 major cities around the world will need to mount globally unprecedented defenses or lose most of their populated areas to unremitting sea level rise lasting hundreds of years but set in motion by pollution this century and earlier.

We have the opportunity now to change this future. Meeting the most ambitious goals of the Paris Climate Agreement will likely reduce exposure by roughly half, allowing nations to avoid building untested defenses or abandoning many coastal megacities.

Climate Central's scientists examined where populations are most vulnerable within the next 200 to 2000 years and under different scenarios of warming. The results are alarming:

- The high tide line could encroach above land occupied by roughly 10% of the current global population (over 800 million people) after 3°C of warming (5.4°F).
- Many small island nations are threatened with near-total loss.
- Parts of Asia face the greatest overall exposure, both this century and later. Asian countries make up eight of the top ten most at-risk large nations (with at least 600 million people exposed at 3°C).
- In China, roughly 43 million people now live on land expected to be below high tide levels after 3°C of warming at the end of this century, and 200 million on land at risk over the longer term.
- China, India, Vietnam, and Indonesia are all in the top five countries most at risk from long-term rise—countries that have added the most new coal-burning capacity from 2015-2019.

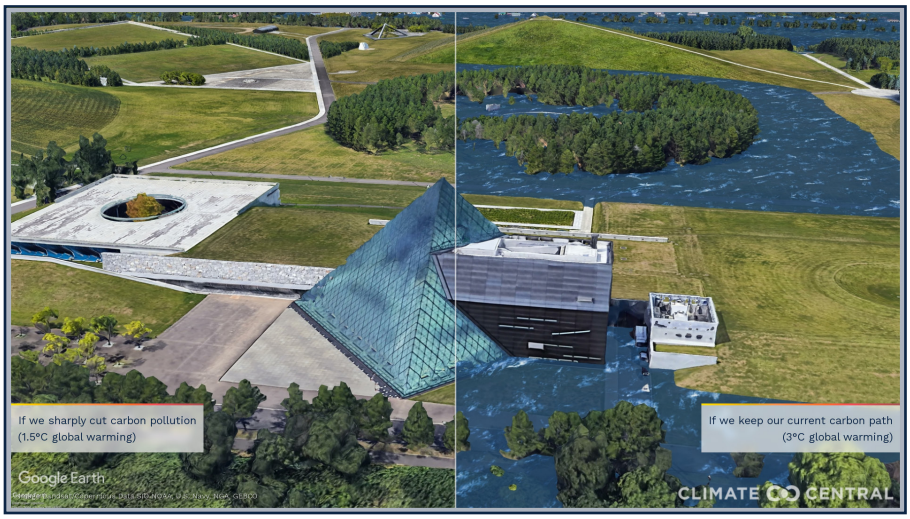
Written in collaboration with researchers at Princeton University and the Potsdam Institute for Climate Impact Research in Germany, Climate Central's peer-reviewed research paper focuses on the contrast between 4°C and 2°C warming scenarios, and appears in the scientific journal Environmental Research Letters. This summary report instead focuses on the contrast between 3°C and 1.5°C scenarios, which correspond to continuing the current trajectory vs. making deep and immediate cuts to climate pollution, dropping to roughly half of today's annual emissions by 2030.

See the Research

PICTURING OUR FUTURE

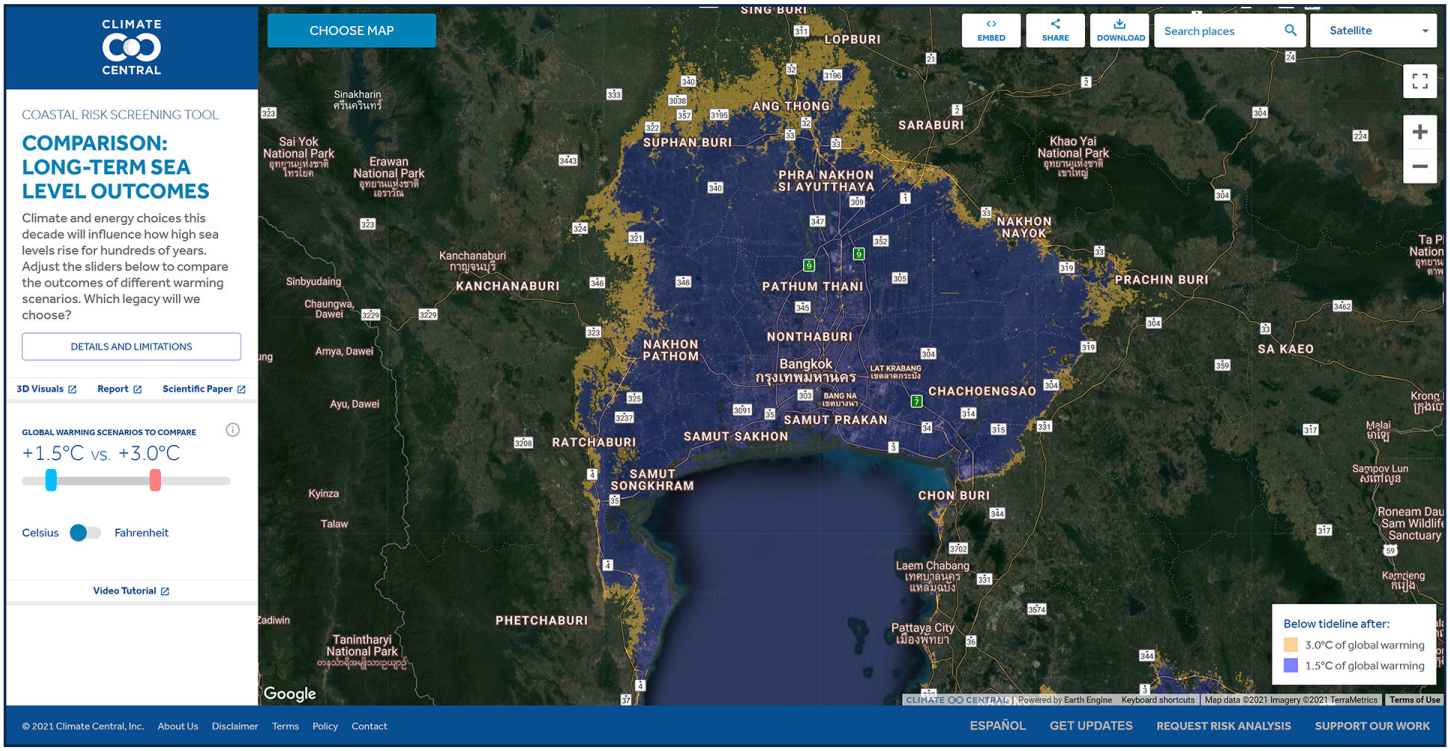
The peer-reviewed research has enabled Climate Central to develop a number of powerful visual tools to communicate the future risks of warming and to show what we can save.

Figure 1. Sapporo, Japan: Projected Future Sea Levels



Utilizing Google Earth images, Climate Central developed **realistic renderings** of coastal locations under different future warming scenarios. Through the Picturing Our Future interface, users can select from among hundreds of images of at-risk sites around the world, including financial centers, stadiums, museums, temples and churches, and other historically or culturally significant buildings. Each image allows toggling between a number of scenarios. Users can look at current conditions and compare where water levels could end up after 1.5°C of warming (if we implement measures to sharply cut carbon pollution) up to 4°C (if we allow unchecked carbon pollution).

Figure 2. Bangkok,Thailand: Coastal Risk Screening Tool



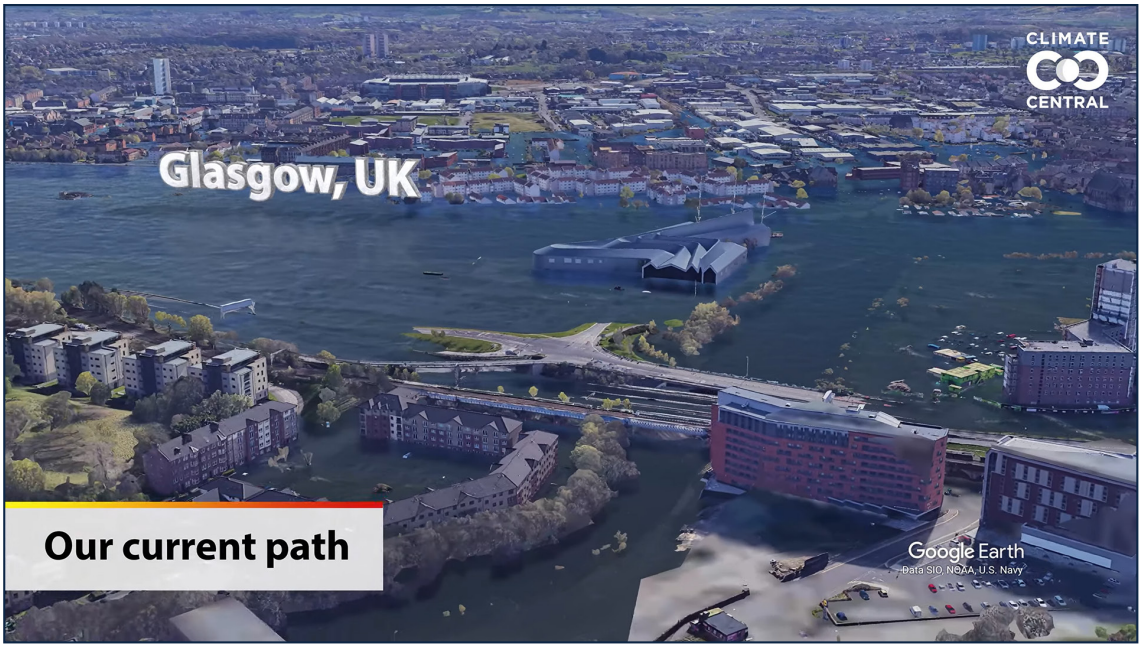
Climate Central's updated **mapping tool** allows users to compare sea level projections after different temperature increases, highlighting the areas that could be saved by reducing our carbon pollution and limiting global warming. Users can enter nearly any global coastal address or location to see where land is projected to be below the high tide line. Sliders allow users to see the projected effects set by different amounts of global warming, from 1.0°C to 4.0°C and can choose between roadmap and satellite settings.

Figure 3. Dhaka, Bangladesh: Projected Future Sea Levels

Climate Central worked with visual artist Nickolay Lamm to create **photorealistic illustrations** of the multi-century sea level rise consequences of 1.5°C and 3°C of warming at a number of iconic locations identified as vulnerable in the research.

Figure 4. Glasgow, United Kingdom: Projected Future Sea Levels

We have created **fly-over videos** contrasting the projected future sea levels after 1.5°C vs. 3°C of global warming in many coastal cities around the world where 3-D building data is currently available in Google Earth.



KEY CONCEPTS

Full differences in sea level rise caused by higher vs. lower emissions pathways will take centuries to unfold—but these consequences will be determined by humanity's actions in the coming few decades. Higher levels of warming will require globally unprecedented defenses against flooding or force abandonment in scores of major coastal cities worldwide. If we limit the warming to 1.5°C through strong compliance with the Paris Agreement, these consequences may be limited to a handful of locations.

Cumulative carbon emissions from human activities in the 20th and 21st centuries are projected to sustain global temperatures for thousands of years. There are a number of reasons for this, including that carbon dioxide remains in the atmosphere for centuries and because of possible feedback loops such as thawing permafrost. The carbon already in our atmosphere is warming the planet 1.1°C—enough for global mean sea level to rise about 1.9 meters (6.2 feet) over the coming centuries, even with no net global emissions after 2020.

Roughly 5% of the world's population currently live on land below where the high tide level is expected to rise (1.9 meters) in coming centuries based on carbon dioxide that human activity has already added to the atmosphere. If carbon emissions are lowered to the proposed limit of the Paris Climate Agreement and warming is kept to 1.5°C, this would lead to a median 2.9 meters (9.5 feet) of multi-century sea level rise, affecting land inhabited by 510 million people today. But if the planet experiences 3°C of warming, the high tide line could encroach above land occupied by as much as 10% of the current global population (over 800 million people).

Threats are global but concentrated in Asia, where megacity futures hang in the balance, and four of the top five global nations building the most new coal capacity are also the most endangered. In absolute terms, China has the most to gain from limiting warming, with roughly 50 million people on land that multi-century sea level rise threatens after 3°C warming, but which is not threatened if warming is limited to 1.5°C.

Many smaller nations, particularly islands, have much higher percentages of their population at risk of exposure. Under a 3°C warming scenario, the Cocos Islands, Maldives, Marshall Islands, Kiribati, Cayman Islands, Tokelau, Tuvalu, and the Bahamas each face a future with land home to more than 90% of their current populations below the median projected multi-century high tide line. With 1.5°C warming, the threat still exceeds 60% for each.

Table 1. *Nations at Risk:* Millions of people currently occupying land below high-tide lines under multi-century warming scenarios

Country	3°C	1.5°C	1.1° (Present day conditions)
Global	810	510	360
China	200	150	110
India	91	58	43
Bangladesh	81	50	35
Vietnam	52	42	36
Indonesia	49	33	24
Japan	38	26	13
Philippines	27	16	11
Egypt	26	9.1	5.6
United States	24	8.5	3.6
Thailand	22	19	16
Brazil	15	5.7	2.4
Myanmar	14	7.4	3.9
Nigeria	8.7	3.7	1.7
Malaysia	8.4	4.8	3.0
United Kingdom	7	4.7	3.2
Mexico	5.7	1.8	0.73
South Korea	5.6	3.2	1.8
Pakistan	5.5	2.7	1.6
Iraq	5	4.4	4.0
Italy	4.4	1.3	0.56

Table 1 note: Populations are median figures, see original paper for 66% confidence intervals. These are the top 20 countries most affected (with populations over 25 million), ranked by multi-century vulnerability after 3°C warming.

Table 2. *Cities at Risk:* Millions of people currently occupying land below high-tide lines under multi-century warming scenarios

Place	Country	3°C	1.5°C	1.1° (Present day conditions)
Shanghai	China	31	27	23
Dhaka	Bangladesh	23	14	9.0
Calcutta	India	15	9.3	7.0
Tianjin	China	14	9.1	6.3
Hong Kong	China	14	11	8.1
Mumbai	India	13	11	11
Jakarta	Indonesia	11	8	6.1
Haora	India	10	6.9	4.0
Tokyo	Japan	9.1	6.9	3.3
Hanoi	Vietnam	9	5.1	3.6
Shantou	China	8.6	5.4	3.3
Osaka	Japan	6.2	3.7	0.77
Surabaya	Indonesia	4.4	3.6	2.9
Shenzhen	China	4.3	3.2	2.4
Karachi	Pakistan	3.3	1.9	1.1
New York	United States	2.4	0.83	0.46
Buenos Aires	Argentina	2.4	1.1	0.01
Quezon City	Philippines	2.3	0.9	0.39
Seoul	South Korea	1.7	0.83	0.45
Rajshahi	Bangladesh	1.5	0.01	0.00

Table 2 note: Populations are median figures, see original paper for 66% confidence intervals. These are the top 20 urban areas most affected (with populations over 10 million), ranked by multi-century vulnerability after 3°C warming.

METHODOLOGY

As detailed in the newly published peer-reviewed research, these findings are based on localized long-term sea level projections published in the Proceedings of the National Academy of Sciences of the United States of America (Strauss et al. 2015), overlain against the AI-based coastal elevation dataset CoastalDEM version 1.1 (Kulp and Strauss 2018) and 100-meter-resolution global population density data from WorldPop. Exposure estimates were aggregated to city level using urban agglomeration boundary data from Natural Earth, and aggregated to national level using administrative boundary data from GADM 2.0.