DIALOGUE

EXTREME WEATHER AND CLIMATE CHANGE

SUMMARY

People, businesses, cities, and states are increasingly burdened by extreme weather events. Drought, heat, wildfires, precipitation, hurricanes, and tornadoes are becoming more intense. Most analysts point toward an emerging trend: as the earth warms, extreme weather events are becoming more costly and more deadly, though some raise lingering uncertainties about linking climate change to specific types of weather or specific events. On June 25, 2020, the Environmental Law Institute (ELI) hosted an expert panel that explored extreme weather adaptation and resiliency efforts in the United States. Below, we present a transcript of the discussion, which has been edited for style, clarity, and space considerations.

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Sarah Kapnick is Deputy Division Leader and Research Physical Scientist at the National Oceanic and Atmospheric Administration.
Paul A. Hanle is the Project Leader of the Climate Judiciary Project at ELI, and formerly President and CEO of Climate Central.
Edward Kussy is a Partner at Nossaman LLP.
Aladdine Joroff is a Staff Attorney and Lecturer on Law at Harvard Law School.

Rebecca Kihslinger: This webinar is part of the Environmental Law Institute's (ELI's) broader work on climate change and resilience. Our current work most recently is focusing on helping governments and communities become more resilient and promoting nature-based adaptation strategies because, as we all know, people and cities and states and governments and businesses are increasingly burdened by the impacts of climate change and extreme weather events. We are developing the strategies and solutions and tools they're going to use to address those events and the impacts that are associated with them.

Last year alone, according to the National Oceanic and Atmospheric Administration (NOAA), the United States experienced 14 weather- and climate-related disasters that had losses that exceeded $1 billion each, totaling about $45 billion.[1] Those billion-dollar disasters included wildfires in California, hurricanes, inland floods, and severe storms. At least 44 people died as a direct result of those events. Many more were injured and many, many lives were significantly disrupted by those events.

2019 was the fifth consecutive year in which there were 10 or more billion-dollar weather- and climate-related disaster events that impacted this country.[2] These events are putting increasing pressure on governments—local, state, and federal—and companies and people to develop adaptation and resilience strategies. So, I'm excited about today's webinar where we're going to talk about these extreme weather events and climate change.

We're going to start by talking about some of the science of extreme weather and climate change, and what the science is saying about how to attribute extreme weather events to climate change. Then we're going to talk about resilience: What is resilience, and what are some of the resilience and adaptation measures that government agencies are starting to implement in response to these events and impacts? How is liability associated with these extreme weather events affecting that decisionmaking and the strategies that governments are coming up with?

We're starting today with Sarah Kapnick, the deputy division leader and research physical scientist at NOAA. Her research focuses on the mechanisms controlling the hydroclimate with an emphasis on precipitation, extreme storms, and mountain snowpack. Sarah's work answers questions about current weather and deviations in the climate system relating to the water cycle. Her research utilizes big data from both observations and models to understand how the climate system has varied in the past and present and what we might expect in the future.

Paul Hanle is the project leader of the Climate Judiciary Project at ELI. He retired in 2018 from his position as president and chief executive officer of Climate Central, which

1. Adam B. Smith, *2010-2019: A Landmark Decade of U.S. Billion-Dollar Weather and Climate Disasters*, Climate.gov, Jan. 8, 2020, https://www.climate.gov/news-features/blogs/beyond-data/2010-2019-landmark-decade-us-billion-dollar-weather-and-climate.

2. *Id.*

he had joined in 2011, reflecting his career-long dedication to increasing public understanding of environmental conservation and science. Earlier, Paul had leadership roles for 24 years as the first president of the Biotechnology Institute, president of the Academy of Natural Sciences of Philadelphia, and chief executive officer of the Maryland Science Center.

Edward Kussy is a partner at Nossaman LLP. He has 40 years of experience holding senior positions in the federal government and is one of the nation's leading experts on federal surface transportation policy and regulations. Previously, he served as the deputy chief counsel at the Federal Highway Administration (FHwA) in Washington, D.C. Over the course of his federal career, Ed has worked on virtually every part of the Federal-Aid Highway Program and aspects of many other federal transportation programs.

Aladdine Joroff is a clinical instructor and staff attorney at the Emmett Environmental Law and Policy Clinic at Harvard Law School. Prior to joining Harvard, Aladdine practiced environmental and land use law in the Boston offices of Beveridge & Diamond and Goodwin Procter, where her work included permitting, operating and regulatory compliance counseling, policy development advocacy, and associated litigation in state and federal courts. She has worked with clients in the private, public, and nonprofit arenas with a focus on energy-sector participants.

Sarah Kapnick: I thought, for those of you who are not scientists, I'd give a little background of what it is I do. I work for NOAA, where I am tasked with understanding and predicting weather, climate, oceans, and coastal resources. Specifically, I work at the Geophysical Fluid Dynamics Laboratory, which is the birthplace of climate models and climate modeling. The work that I do uses supercomputers. The room is filled with panels—each of which is larger than a person—to create giant supercomputers. I work with large climate models that are run on large supercomputers to be able to generate analysis and data and understanding of the earth's climate. We run our models and then we analyze them to try to understand weather and climate.

How do we understand weather and climate? What do we know about climate change and why? There are two main ways in which we are trying to assess weather and climate. First, we have the observed data that we've collected over decades of the weather and climate just in the United States. There are weather stations throughout the country. In a weather station, you have measurements of precipitation, sunlight, evaporation, and temperature. The automated weather stations are taking these values that we can use to understand how weather and climate are changing over time. We have stations going back to the 1800s.

Second, we now have satellites. The satellite era since the 1980s has been a boon for us for understanding the climate remotely. This allows us to uniformly monitor climate everywhere, because weather stations aren't located at high elevations or in uninhabited places and can't blanket the earth in the way satellite can. So, you can have gaps in the data from our weather station measurements on the ground with satellites providing us with more information.

However, we only have 40 years of data from the satellite era. As a result, we don't have a full picture of what the climate has been over time because we may have gaps in our data. As a result, climate models have been used to fill in those gaps, to be able to simulate climate to understand what's happened in the past. We also use it to try to project and look at what will happen in the future.

I was asked to talk about extreme weather and climate. The way that we use our climate models is to generate large data sets, with many different realizations of the past and future (i.e., we create multiple possible worlds and generate hundreds of years for each one) to create thousands of years of data and to use that to calculate the risks of extreme events. We use it to calculate the probability of an event, how that probability might be changing, why that probability is changing—is it due to increased greenhouse gases, is it chance, is it aerosols?—and what those probabilities are going to be in the future.

Fundamental to all of this, scientists also like to quantify the uncertainties—why do we know what we know, what uncertainty might there be in our calculations, and what do we need to do in the future to improve it? Scientists, like myself, like to say we know that this is the risk and this is how we need to figure out a better idea of what the risk is in the future and reduce that uncertainty.

Extreme weather events cause harm to lives and property. In statistics, we refer to these as extreme events as low-probability events. If you look at a distribution of probability, you have your average climate. But then you have these extreme events, the things that don't happen very often but they're the most extreme realization. That means extreme precipitation events, such as flooding or an extreme snowstorm. Then, a negative precipitation extreme gives you extreme drought and very dry soil.

By definition, extremes don't happen very often. We have our historical record to be able to characterize extremes. But you may only have a few years, a few decades of data, and you might not actually be able to have all those realizations of the risk of extremes in those extreme tails. Partly, on climate change, the complication that arises is these extremes may be changing. How you characterize extremes and changes in extremes from observations alone is very difficult when you have a changing climate. That is what my work focuses on, using climate models to be able to allow us to characterize extreme events, the likelihood today, what it was in the past, what it is in the future, and how it is changing and why.

2019 was a really big year. There were 14 separate billion-dollar disasters. Over the past 40 years, there have only been nine years in which we've had 10 or more billion-dollar disasters.[3] We've had 10 or more in the past five years alone.[4] So in the past few years, there have been more of these billion-dollar disasters. They've been increasing the

3. NOAA, *Billion-Dollar Weather and Climate Disasters: Overview*, https://www.ncdc.noaa.gov/billions/ (last visited Oct. 26, 2020).
4. *Id.*

number of the entire record. There are questions about why this is happening. We are doing extensive research on the extreme events to have a better understanding of the risks of these major extremes and how they may be changing.

I will give you a few examples. The National Climate Assessment, a quadrennial exploration of extreme precipitation in the United States, breaks the United States up into different regions.[5] The Midwest and the East Coast have precipitation extremes increasing the most over the historical record. Then you have two different scenarios: middle-of-the-road scenario and a higher scenario of expected increases in greenhouse-gas forcing. In the high scenario, you have much larger increases in extreme precipitation over the northeastern portion of the United States. Extreme precipitation is problematic because it leads to flooding. It leads to crop damage. It can lead to low water-quality events. It can also lead to mudslides and land floods.

Other extreme events are winter storms and snowfall. With the changes in extremes, we expect that there is going to be less snowfall overall on average in the United States. However, in the extreme tail, we actually see the most extreme events. That risk may be increasing in that scenario where we are still doing more research because of the uncertainty around those changes. But we're seeing there may be increases in the most extreme events. Again, overall snowfall is declining and the number of blizzards that are experienced is declining, but there may be upticks in the most extreme events.

Next, I will talk about tropical cyclones. Over the past roughly 40 years, there have been more tropical cyclones, particularly in the Atlantic Ocean.[6] Storms have been increasing over the past 40 years; however, there's some uncertainty of why that is. Some research has just come out to suggest that aerosols are part of that, that differences in aerosols may have led to increases in the number of storms over that period versus the period before.[7]

So, the future number of storms is a big question. That is one that has a lot of uncertainty because a lot of modeling actually shows that there's a decline by the end of the century in the total number of storms. But there's the question of what the strengths of the storms are going to be. However, even if the number of storms doesn't change or the strengths of storms don't change, because of sea-level rise with the average level of the waters increasing, the same storm that creates storm surge will actually cause more flooding than storms in the past even if the storm numbers or strength does not change.

Sea levels in certain U.S. regions have already increased by one foot since 1900; here, we will use the example of New York City, where they have carefully assessed past sea level.[8] There's an expectation of one foot to potentially five feet by the end of the century.[9] This difference of one foot to five feet sea-level rise gets you to average conditions being lower Manhattan underwater or parts of Brooklyn and Queens underwater by the end of the century. This doesn't even include an extreme event or storm.

Picture, for example, Coney Island in Brooklyn. The parking lot and area where people usually picnic, that whole region would be underwater by the end of the century on the moderate to more extreme scenarios. So, with the climate data and understanding extremes, a lot of the work that I'm discussing now is about the risk assessment. We're trying to understand the risks. We're trying to better assess what they are and how they might be changing.

Another aspect of this work is risk management. When we have this information, can we predict it? Can we build systems to be able to predict an event by weeks, by months, by season to try to reduce the impact of these risks? Then in talking to this panel, I'm very curious to receive people's feedback about how we can develop better data for decisionmaking and user needs.

Before pursuing a Ph.D., I actually worked on Wall Street as an investment banker. I worked on catastrophe risk, catastrophe bonds. In coming to science and then coming to NOAA, one of my main goals is to try to produce better data to understand these risks. I think this is an incredibly powerful thing, an opportunity that we have with these climate models to produce better assessments of risk and data for understanding risk into the future relating to climate.

I want to leave you with additional material should you need it. Every state regionally has a state climatologist.[10] They also have regional climate centers and service directors that work together with NOAA that can provide you with regionalized information.[11] In your state, there's a regular national climate assessment every few years mandated by the U.S. Congress for which we produce information about the state of the climate.[12] This is a multiagency effort across the federal government.

NOAA also has the U.S. Climate Resilience Toolkit where you can find more information about resiliency and climate data.[13] Some helpful resources on the site for nonscientists include the drought maps and the Climate at a Glance page. The toolkit allows you to visualize climate information in your region.

Paul Hanle: Can science attribute damage from extreme weather to greenhouse gas emissions? That question has

5. U.S. Global Change Research Program, *Fourth National Climate Assessment*, https://nca2018.globalchange.gov/ (last visited Oct. 26, 2020).
6. Hiroyuki Murakami et al., *Detected Climatic Change in Global Distribution of Tropical Cyclones*, 117 Proc. Nat'l Acad. Sci. 10706 (2020), *available at* https://doi.org/10.1073/pnas.1922500117.
7. *Id.*
8. Radley Horton et al., *Appendix D* in New York City Panel on Climate Change 2015 Report Chapter 2: Sea Level Rise and Coastal Storms, 1336 Ann. N.Y. Acad. Sci. 36 (2015), https://www1.nyc.gov/assets/planning/download/pdf/applicants/wrp/wrp-2016/nyc-wrp-appendixd.pdf.
9. NOAA, *Sea Level Rise Viewer*, https://coast.noaa.gov/slr/ (last visited Nov. 13, 2020).
10. American Association of State Climatologists, *Home Page*, https://stateclimate.org/ (last visited Oct. 26, 2020).
11. *See* NOAA National Center for Environmental Information, *Regional Climate Centers*, https://www.ncdc.noaa.gov/customer-support/partnerships/regional-climate-centers (last visited Oct. 26, 2020) and NOAA National Center for Environmental Information, *Regional Climate Service Directors*, https://www.ncdc.noaa.gov/rcsd (last visited Oct. 26, 2020).
12. *See* U.S. Global Change Research Program, *supra* note 5.
13. U.S. Climate Resilience Toolkit, *Home Page*, https://toolkit.climate.gov/ (last visited Oct. 26, 2020).

some legal ramifications that I'm going to discuss at the end. I want to talk about how swiftly attribution science has developed, and also how it may come to bear on climate arguments in court cases.

There is a nifty 30-second video loop of global temperature change that the National Aeronautics and Space Administration (NASA) has put together.[14] It uses a color scheme going from blue, which is on the cooler side and below average, all the way up to red, the higher end, above average. Over 140 years, you can see what's been happening globally.

The video shows a gradual rise in temperature. Starting at 1880, the global distribution of heating appears as small, dispersed spots. Then, as you approach 2019, virtually the entire globe turns red above average, where average lies approximately at 1950. These are actual measured temperatures. The evidence for warming is unequivocal. There is no dispute within the expert scientific community about it.

But the video shows nothing about the sources of the heat. In fact, the source is largely excess energy trapped by global greenhouse gas emissions. The greenhouse gases are driving the warming. The biggest component of these is carbon dioxide (CO_2). There are other greenhouse gases that are more powerful but also are emitted in lower concentrations or have shorter lifetimes. And as Sarah pointed out, aerosols may have negative effects that offset some of the heating. So there is a netting out of the whole heating effect. But overall, the earth is warmed by the increase in greenhouse gas concentrations in the atmosphere.

Paleoclimate evidence from ice cores allows measurement of concentrations of CO_2 over nearly one million years. While there is natural variability of CO_2 concentrations between about 180 and 300 parts per million over almost all of the 800,000 years shown, the trend line over time remains flat until about 150 years ago.[15] But then, from the early 1900s into the present time, with increasing emissions of CO_2 beginning in the Industrial Revolution, the concentration shoots rapidly up and beyond 400 parts per million—at a rate unprecedented in geological history. That number now is 410 parts per million and continues its rapid climb.[16]

How do we know that it's actually the greenhouse gases that are the drivers of warming? Well, the expert Intergovernmental Panel on Climate Change in its 2013 report demonstrated that we can run what's called a counterfactual, dynamic model of the earth without additional greenhouse gases and obtain the "flat curve" expected without fossil fuel emissions.[17] But as we saw, observations show that warming is increasing. If you run the model with the additional greenhouse gases from burning—the real condition of the atmosphere—you add what is called the "human forcing" and the models pretty well match the observations, within the calculated uncertainties.

So, what is established is this: that climate change is real, it's human-caused, and it has consequences. One of the consequences, again as Sarah pointed out, is that there is an increase in the frequency of extreme events. The shift of the curve of probability of a given kind of event skews toward both more frequent and more intense extreme events as the earth heats. There is a growing recognition that extreme weather is happening more often, and that events of certain kinds are becoming more intense.

Several groups of climate scientists at the beginning of the 21st century decided to try to figure out if the increases in frequency of occurrence or magnitude of any particular extreme event can be attributed to global warming, and to develop a research program for what is called "extreme event attribution."[18] A number of programs had then begun to produce results, enough so that the National Academy of Sciences decided it should conduct a consensus study of the state of research in extreme event attribution.[19] The study reported that in the past, scientists' typical responses to questions about climate change were that you cannot attribute any single individual event to climate change. We heard this repeated by all sorts of spokespeople, ranging from leading climate scientists to the president of the United States.

The National Academy wrote in this report, though, that "It is now often possible to make and defend quantitative statements about the extent to which human-induced climate change . . . has influenced either the magnitude or the probability of occurrence of specific types of events or event classes."[20] This has immense implications for recognizing why the event happened, what were its causes, and thus for legal cases as well.

One of the analyses of an extreme event that's very interesting—stepping back for a moment—is one that was done at Sarah's laboratory, the Geophysical Fluid Dynamics Laboratory, in collaboration with the Royal Netherlands Meteorological Institute and other partners in the World Weather Attribution group. This group was created by my former organization, Climate Central, and Oxford University.[21] The result of the analysis of the very heavy rains that occurred in Baton Rouge, Louisiana, in 2016 was that there was a 40% increase in the likelihood of this event taking place because of the presence of greenhouse gases.[22]

14. 135 Years of Global Warming in 30 Seconds, Climate Central (Jan. 16, 2015), *available at* https://www.youtube.com/watch?v=---FX0tFCww.
15. Rebecca Lindsey, *Climate Change: Atmospheric Carbon Dioxide*, Climate.gov, Aug. 14, 2020, https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide.
16. *Id.*
17. Nathaniel L. Bindoff & Peter A.Stott, *Detection and Attribution of Climate Change: From Global to Regional*, *in* Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (T.F. Stocker et al. eds., Intergovernmental Panel on Climate Change 2013).
18. Thomas C. Peterson et al., *Explaining Extreme Events of 2011 From a Climate Perspective*, 93 Bull. Am. Meteorological Soc'y 1041 (2012), https://journals.ametsoc.org/bams/article/93/7/1041/92412/Explaining-Extreme-Events-of-2011-from-a-Climate.
19. National Academies of Sciences, Engineering, and Medicine, Attribution of Extreme Weather Events in the Context of Climate Change (National Academies Press 2016).
20. *Id.*
21. Karin van der Wiel et al., *Rapid Attribution of the August 2016 Flood-Inducing Extreme Precipitation in South Louisiana to Climate Change*, 21 Hydrology Earth Sys. Sci. 897 (2017), *available at* https://hess.copernicus.org/articles/21/897/2017/.
22. World Weather Attribution, *About*, https://worldweatherattribution.wordpress.com/about/ (last visited Nov. 13, 2020).

My colleague Heidi Cullen noted that within the distribution of probability of occurrence, however, if you go not to a very conservative but to the most likely contribution, it was actually a doubling of the probability of occurrence.[23] This is relevant because one legal standard for proximate cause of an event is 50% or greater contribution of an act.

By far, the most firmly attributable kinds of events are heat waves. That is because they are the direct consequence of heating the entire earth system. One example of this kind was the Australian heat wave of 2016-2017. An attribution analysis of this very deep and long heat wave concluded that its maximum temperatures were 10 times more likely because of the presence of heat-trapping gases.[24] That is to say that climate change contributed 90% of the probability of the event occurring. You might note that that percentage is comparable to the persuasive correlation of smoking to the incidence of lung cancer, and obviously well above the 50% preponderance of evidence threshold.

Another event analyzed was Hurricane Harvey.[25] Several groups, including the World Weather Attribution group, took part in the analysis and found that the event was about three times more likely than it would have been without greenhouse gases. Moreover, it was made about 15% worse in magnitude of rainfall.[26] Since that event was defined as the height of the rain around Houston, at least 50 inches of rainfall, 15% worse means that the last seven or eight inches were attributable to climate change. Imagine the implications of that extra rain for overtopping dams and consequent damage from flooding from those extra inches of water.

I want to call your attention to a commentary in the journal *Nature* of such analyses by the nonprofit group ClientEarth, which described the status of attribution and how it will likely be brought to bear in legal considerations.[27] In it, they note rainfall increases and event likelihoods. But they also note that predictability—being able to do such analyses and showing trends over time—also has legal consequences, for example, for states' and corporations' duties of care.

For those who plan to build infrastructure, public housing, or utilities, there now is a growing obligation—because of the advancing state of the science—to be thinking about how climate conditions will be changing over time. This obligation applies as well to states, private professionals and companies' disclosure of material risk, investment risk, liability of corporate boards, and a whole range of other duties.

The science is rapidly moving. There certainly are significant uncertainties that go beyond what I have described here, and important conclusions that have yet to be revealed. At the Climate Judiciary Project, we think the judiciary should have the opportunity to understand the science regarding which they will need to weigh evidence, to have a sense of what's known and what's not known, and the degree of uncertainty associated with that which is known. To this end, we plan to develop a curriculum about climate science for judges, many of whom have expressed very strong interest in learning more about it, as they anticipate cases coming before them.

Edward Kussy: I'm going to talk more about some of the practical consequences of climate change and other events and about resilience in the face of extreme weather events. I will focus on transportation structures and how they're vulnerable, what can be done to lessen that vulnerability, and then who pays and what is the role of various government agencies in dealing with or trying to lessen vulnerability.

What is resilience? The FHwA has a definition, probably as good as any, which is "the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions."[28] Our transportation facilities have to be resilient against a number of factors that really have nothing to do with climate change. First, of course, is wild weather. That's not a term of art. Wild weather can be a drought, a storm, a snowstorm, or anything that affects transportation facilities due to weather.

Of course, climate change induces sea-level rise and heat consequences. You also have earthquakes and fires, vehicle crashes, and terrorism. Following 9/11, for example, many transportation structures were reviewed for their resilience against terrorism and possible consequences.

Resilience is really based on risk assessment. And it's a cost analysis: what does it cost versus what is the risk. It does not mean preparing for the worst possible occurrence in every case. That is very unlikely unless that occurrence is really catastrophic. We have very strong standards for things like nuclear reactors because the consequences of a meltdown are very serious. What we think about as a risk analysis changes as our perception of threats change over time.

The consequences of climate change have been a concern for quite some time. The first efforts of transportation officials to deal with sea-level rise and increased storms go back to the 1990s. So this is not new. The literature that talks about what we should do goes back that far.

Transportation facilities are vulnerable. One thinks of big and heavy highways as not having that much vulnerability, but that is not the case. For example, Hurricane Katrina undermined the structural integrity of a bridge

23. John Upton, *Louisiana Floods Directly Linked to Climate Change*, Climate Central, Sept. 7, 2016, https://www.climatecentral.org/news/louisiana-floods-directly-linked-to-climate-change-20671; Henry Fountain, *Scientists See Push From Climate Change in Louisiana Flooding*, N.Y. Times, Sept. 7, 2016, https://www.nytimes.com/2016/09/08/science/global-warming-louisiana-flooding.html.
24. Andrea Thompson, *Warming Had Clear Hand in Record Australia Heat*, Climate Central, Mar. 2, 2017, https://www.climatecentral.org/news/warming-clear-australias-record-heat-21204.
25. Geert Jan van Oldenborgh et al., *Attribution of Extreme Rainfall From Hurricane Harvey, August 2017*, 12 Env't Rsch. Letters 124009, *available at* https://iopscience.iop.org/article/10.1088/1748-9326/aa9ef2.
26. *Id.*
27. Sophie Marjanac et al., *Acts of God, Human Influence and Litigation*, 10 Nature Geoscience 616 (2017), *available at* https://doi.org/10.1038/ngeo3019.
28. *See* FHwA, FHWA Order 5520: Transportation System Preparedness and Resilience to Climate Change and Extreme Weather Events, para. 6.e (Dec. 15, 2014), https://www.fhwa.dot.gov/legsregs/directives/orders/5520.cfm.

in Mississippi.[29] There were consequences. Earlier in the 1990s, on Interstate 90, just before it goes into Seattle, an unexpected storm swamped the bridge while it was being maintained.[30] The whole bridge sank next to a new section that did not.

How are transportation facilities vulnerable? One way is bridge scouring—when swiftly moving water comes at a bridge and its substructure, the force of the flow undermines the integrity of the bridge. That can lead to the bridge losing its structural integrity.

Bridges and culverts may not be adequate for high water flows. That has the impact again of scouring or, in the case of a culvert, undermining the structural integrity of a highway embankment. But these things can also act as a dam. If you have very high water flow like a surge or a flood and the culverts are not adequate, it becomes a dam.

A highway subbase can be compromised through a variety of means. It can be drought, which causes it to shrink. It can be water flow, which leads to pavement collapses. In Hurricane Sandy, even some subway stations were flooded.[31] High winds, flooding, and snowstorms can disrupt operations. A number of years ago, a mayor of Chicago actually lost reelection because he could not get the streets in Chicago cleaned in time.[32] But these events become stronger and stronger. It's not just big snowstorms, but flooding and high winds that can affect original integrity.

Heat can stress pavements of all types. Concrete pavements expand and then break apart because there is nowhere for them to expand to. Asphalt pavements may become softer and wear more quickly. Then, of course we all "enjoy" lots of the potholes we see on streets because of seasonal changes in temperature. That's what causes potholes.

How is resilience achieved? You can include resilience in transportation planning. Federal law requires every state and every municipal area or urban area of more than 50,000 people to have transportation planning. These may, but are not required to, address resilience as part of their planning, looking at how we make structures more stable.

Then, there is project development. This includes environmental analysis under the National Environmental Policy Act (NEPA).[33] It also includes looking at alternatives and different ways to plan and locate projects. You can discourage development in risk-prone areas. There are a number of laws, like the National Flood Insurance Act and the Coastal Barrier Resources Act,[34] that try to use the lack of insurance or the lack of support to discourage development in areas like coastal barrier islands that are high-risk-prone areas.

We've lost a tremendous amount of wetlands in the United States. Wetlands are very important for reducing the impacts of floods and surges. You can actually, as part of environmental planning, restore some of these areas. As has already been mentioned, climate change leads to avalanches. It also leads to mudslides. Mudslides can be avoided through appropriate planning measures. In fact, natural-mapping initiatives can work as well as anything else to avoid slides.

Bridges and culverts can withstand higher flooding volumes. This is very important when you are doing construction in areas where the sea level is rising. There you can strengthen or modify structures. You can put highways and transit lines on viaducts instead of on a causeway. You can construct bridges in a manner that reduces scouring. And of course, you can relocate or put new facilities in safer locations. In fact, on occasion, transportation structures subject to frequent damage by weather events have been moved to more stable locations.[35]

Who pays and whose highway? How does the federal government interact with state and local governments? Transit and highway projects in the United States are built, operated, and maintained almost entirely by state and local agencies. The federal government is only directly responsible for these facilities on federal lands like national parks, national forests, and so on. So the federal government, primarily the FHwA and the Federal Transit Administration, provides funding to state and local agencies. These fundings come with a number of conditions like environmental analysis, transportation planning, and meeting of standards. But the decision as to how to build and where to build is largely left to the states and local governments.

Federal highway funds are distributed to the states in various categories through the National Highway System and the Transportation Improvement Program of the FHwA. These are allocated to the states and apportioned to the states by a formula that reflects population and area. All these things are taken into account, for both rural areas and urban areas. But the amount of money that a state gets is fixed by a formula. Large transit funds are paid for with particular emphasis on the project, but also some funds are paid for through formulas.

In the United States, about $50 billion a year is allocated to highways, which represents about one-third of what all levels of government spend on transportation, $150 billion.

29. The destruction caused by Hurricane Katrina is cataloged in many places. See, for example, the following document published by AASHTO: *Mississippi DOT Recalls Major Bridge Work After Katrina, Rebuilding of US 90*, AASHTO, Aug. 28, 2015, https://tsp2bridge.pavementpreservation.org/2015/08/28/mississippi-dot-recalls-major-bridge-work-after-katrina-rebuilding-of-us-90/.
30. The sinking of the Lacey V. Murrow Memorial Bridge was also extensively reported. *See, e.g.*, *Lacey V. Murrow Memorial Bridge Sinks to the Bottom of Lake Washington*, History, Jan. 27, 2010, https://www.history.com/this-day-in-history/lacey-v-murrow-memorial-bridge-sinks-to-the-bottom-of-lake-washington.
31. *New York's Damaged and Flooded Subways After Hurricane Sandy Made Landfall*, N.Y. Daily News, https://www.nydailynews.com/news/new-york-damaged-flooded-subways-hurricane-sandy-made-landfall-gallery-13591607.
32. *See* Stephan Benzkofer, *1979 Blizzard Was Debacle*, Chi. Trib., Jan. 5, 2014, https://www.chicagotribune.com/news/chi-the-blizzard-that-got-jane-byrne-elected-20141114-story.html.
33. 42 U.S.C. §§4321-4370h, ELR Stat. NEPA §§2-209.
34. National Flood Insurance Act, Pub. L. No. 90-448 (1968); Coastal Barrier Resources Act, Pub. L. No. 97-348 (1982).
35. *See* Adaptation Clearinghouse, *Caltrans Devil's Slide Realignment Project*, https://www.adaptationclearinghouse.org/resources/caltrans-devil-eys-slide-realignment-project.html (last visited Nov. 13, 2020).

The federal transit budget is about $12 billion. That represents about 25%.[36]

It used to be that federal highway funds were only available for building new highways and everything else was left to the state. Over time, more and more major reconstruction or rehabilitation is not eligible. Preventative maintenance, which is a forward-looking area, that's available.

Agencies have more and more flexibility to actually use funds for things that we would call resilience. However, the decision to do that is still with the state and local governments. The FHwA's share on these projects, and also transit, ranges between 50% and 90% depending on the type of project that is involved.[37] But the primary federal role in the past has been to provide guidance and how to plan for and implement actions that support transportation resilience. There is an enormous amount of material that is available on the FHwA's website.[38]

Disaster relief, which is an important part of resilience, works differently. Federal disaster relief is available when a disaster is declared by the governor of a state with the concurrence of the secretary of transportation, or, in the case of major disasters, by the president.[39] For disaster relief projects of rehabilitating the facilities that are damaged by disasters—which can be fires and droughts, or any number of things—the federal government pays for those things that are eligible between 90% and 100%.[40] In the federal statute, there is a $100 million fund set aside for dealing with disasters, all disasters in any given year.[41] As you just heard, we have far more disasters than that. So almost every year, a massive supplemental appropriation is required to pay for the things that the government actually does.

Disaster relief is largely limited to the cost of repair or replacement up to the current standards. So, betterments, things that improve the project or design it differently so it is more resilient, are not eligible for disaster funds but are eligible for regular highway funds or regular transit funds. There is no special fund in current law that is focused expressly on resilience. Right now, the current federal surface transportation programs are reauthorized every few years. The current transportation authorization will expire in September 2020. If Congress does not pass a new authorizing statute by then, continuing resolutions are likely to keep the program operating.

In an election year, most often these things get extended through continuing resolutions. That is what is happening this year. Both the U.S. House of Representatives and the U.S. Senate bills have in them a special category of funding focused exclusively on resilience. However, since these bills will not be enacted by this Congress, a new authorization bill will be required in the new Congress.

36. See the following focus paper prepared by the Congressional Research Service: Congressional Research Service, Reauthorizing Highway and Transit Fund Programs (2019), https://fas.org/sgp/crs/misc/IF11125.pdf.
37. 23 U.S.C. §120.
38. FHwA, *Home Page*, https://highways.dot.gov/ (last visited Oct. 26, 2020).
39. 23 U.S.C. §125(d).
40. 23 U.S.C. §125.
41. 23 U.S.C. §125(c)(2).

Aladdine Joroff: What we've heard already really illustrates that creating resiliency to climate change impacts, particularly for extreme weather events, is complex, not just because it's costly, but also because nature often doesn't recognize jurisdictional boundaries. So, how do we need to coordinate our approaches? Oftentimes, unlike climate change mitigation, we initially think of resiliency from the local perspective.

If you're thinking, for example, about heat waves, a common resiliency or adaptation measure is to create cooling centers so that community members have a place to go to that's air-conditioned when the temperatures are unsafe in their homes. That's a very local issue and there's a lot riding on it. It might sound easy to do, but you have to consider whether the cooling center is within the area that the people who need it can access, and how they will access it. If it's for older citizens, how are they going to get there?

But then the issues go up in size when you look at, say, flooding along major rivers. Three of those billion-dollar storm events or weather events in 2019 that were mentioned before were flooding along the Arkansas, Mississippi, and Missouri Rivers.[42] And situations like that affect many states, so you need bigger coordination to address the issues. We sometimes see participation at the federal level, like Executive Orders. For example, President Barack Obama had one about development in floodplains and elevating new structures.[43] But when looking beyond recovery funding, more action is often seen at the state and local levels.

What I want to focus on is how local communities in particular try to coordinate on these multijurisdictional problems, which create, I think, an extra wrinkle in the issues local governments face and then the type of work lawyers and consultants do when assisting them.

One thing to start with is a reminder of why climate change adaptation problems are difficult to solve. We've heard a lot about this already. We have to consider both whether we know what the problem is and whether we know how to solve it. When you can say yes to both of those, you're doing reasonably well. It's easier. That's when a lawyer or a consultant can come in and they're really expected to play a more traditional role. For example: "Here's the issue. Here's your budget. Go get us our solution."

If we look at wildfires in California, for example, we know that in dry conditions electricity wires can contribute to causing these fires. We know what one way of solving it is, but we don't like it. For example, this year, Pacific Gas and Electric (PG&E) had proactive blackouts where they limited service to prevent wildfires. As a society, that was not what many people found an acceptable solution. Even when you know how to solve it, it doesn't mean you have either the financial capacity, the political support, or other support needed to go ahead with that solution. And then there are situations where we know the problem but don't yet know the solution; and hardest still are situations

42. *See* Smith, *supra* note 1.
43. Exec. Order No. 13690, Establishing a Federal Flood Risk Management Standard and a Process for Further Soliciting and Considering Stakeholder Input, 80 Fed. Reg. 6425 (Feb. 4, 2015).

in which we don't know either the full scope, timing, or parameters of the project or how to respond to solve it.

I think what we're seeing is that communities are still looking at a really wide array of responses. Rebecca mentioned using nature; this could include, for example, natural resources like living shorelines. Communities might be looking at other tools, from re-expanding floodplains and wetlands, to seawalls and harder infrastructures, to retrofitting buildings, to updating codes for new buildings, to retreat. There's not a lot of appetite yet for retreat, but it's something that needs to be thought about. And there is space in this arena for the private sector as well. For example, some insurance companies are now basing their premiums on facilities putting in adaptation resiliency measures, particularly if they're going to be in areas exposed to strong weather events.

I'm from Boston, so I like to use the word "wicked," so I describe climate change adaptation as a wicked problem, characterized by five features: incomplete and evolving information; no clear solution; diverse stakeholders; large economic burdens; and interconnection with other problems. Sarah addressed the first prong—that we have incomplete and evolving information. For example, if the models show we might have one to five feet of sea-level rise, it's a big planning difference depending on what you're building—say a seawall or a natural shoreline.

Even if you select a data set and the state or municipality makes a decision, what do they do when there's new and better data out there? If they're two or three years into a planning project, do they change it? How do they put adaptive responses into their own adaptation planning and implementation? What margin of error should they use? And what if they're wrong? As Paul talked about, knowledge creates more liability for communities if they're not responding or not responding appropriately to climate change risks and harms. Again, it needs long-term political and financial support.

As the discussion today has already touched on, there is often no consistently clear solution. So, you don't want to tie in your consequences with actions today. If you're building a seawall, it takes a long time to build. We've seen this with traffic projects. We've seen it with other street elevation projects. By the time you're done, the impacts have already caught up with what you built for and you're now just at the status quo. You have to start thinking again about the next wave of impacts.

Also, to follow up on something that was said earlier, you don't always prepare for the worst possible outcome. Municipalities and states, the funders, have to consider whether they are trying to develop projects that will protect the most individuals at risk or the individuals least able to respond to risk. Similarly, is it worst-case scenarios or the most probable scenarios where local governments are putting their limited financial resources as a starting point?

The economic burdens of adaptation efforts can be a significant complication, as are the interconnections between problems. As an example, ELI had a podcast a couple of months ago about air-conditioning and how a lot of localities are looking at mandating air-conditioning in new facilities as an adaptation measure.[44] But how does that work with our goal of reducing the greenhouse gas emissions of our systems? If we require air-conditioning that is electrified, do we need to specify that it should be electrified with green energy?

There are diverse stakeholders to consider. When you're pulling together groups to address adaptation, I'd like to think of it as you're trying to put together the convinced, the convincibles, and your opponents. You're focusing your efforts usually on the convincibles and you're looking at your messaging to see if you can draw in some of your opponents. For example, you don't always have to talk about climate change; you could talk about flood risks if climate change is not an accepted issue.

Different phases in projects can also impact the type of work people are doing. Such phases can include recognizing the problem, which includes defining the goals of a project and creating a narrative; innovating, which includes designing approaches and solutions for a project; and implementing the project. I'd say in the climate change adaptation context in particular, these are iterative phases. You can be going through all three of these at the same time because, as we learn more information, that's going to inform our design solutions and implementation.

I want to talk now about an example of communities that have been doing this kind of joint resiliency work in South Palm Beach County.[45] There, a group of communities came together to work together on resiliency issues, starting with the preparation of a joint climate change vulnerability assessment. A vulnerability assessment is a process in which communities look at their risk exposures and existing adaptive capacities. Using this information, communities then evaluate the impacts that they need to be worried about from climate change.

Reasons for the communities in Florida to work together included the belief that there is value in the increased efficiencies from collaboration and leverage with respect to actions like putting out contracts for bids. But there are also practical implementation reasons; if one town builds a seawall in front of its community, it doesn't do much good unless it's a coordinated effort with its neighbors.

When you have these joint projects, a question that comes up is how formal the coordination should be. As we saw, states responding to COVID-19 said they would coordinate on reopening plans and they would coordinate on barriers, such as letting people come in and out of the state. But the states are not committing to something with each other that's more formal, say, should they all sign an agreement and be committed to a project together.

I think the more formal the approach, the question becomes how much participants are willing to commit. If you have a dozen communities signed up to do a vulnerability assessment together it's a great starting point. But

44. People Places Planet Podcast, *Cool Cities: A/C Ordinances—The Hot New Trend*, Envtl. L. Inst. (Jan. 8, 2020), https://www.eli.org/podcasts.

45. For information about the Coastal Resilience Partnership of Southeast Palm Beach County, see Palm Beach County, *Coastal Resilience Partnership*, https://discover.pbcgov.org/resilience/Pages/CoastalResiliencePartnership.aspx (last visited. Nov. 13, 2020).

how can you keep that infrastructure in place so that, when it's time to start implementing the adaptation measures, they can keep working together within that framework? For example, with stormwater management infrastructure in some smaller communities, they already have contracts with other towns to do some of that work for them. They want to keep that coordination and the question is how to expand it and how to use existing relationships and governing structures to accommodate further resilience work.

There are other things to think about in these joint efforts on adaptation; one big item is the cost allocation. Because when you have a typical inter-municipal effort, say a school that's shared by a few communities, the costs can be split by readily measurable factors such as the number of students from each town. Or trash pickup, you can do it by weight or number of households. With adaptation, it may be a little harder to figure out what benefit each community is getting.

This was an issue on which the Emmett Environmental Law and Policy Clinic worked. We looked at what could be metrics for cost sharing both on the input side and the output side, to create a tool to evaluate if you have a good cost distribution system. The goal being that you want to be able to combine the efforts of larger and smaller entities. On the input side (i.e., factors for dividing costs), we considered administrative costs, which could be a flat fee, population, vulnerability, median income, property value, and per capital property value. On the output side (i.e., factors for evaluating cost distributions), we included percent of total contribution, per capita cost of contribution, and contribution as a percent of total property value. In addition to these quantitative metrics, you might have factors like work in lieu of part of a payment. For example, a smaller community could take on the administrative burden of leading a procurement process for a contract and waive some of its participation fee in exchange, thereby using its existing internal resources instead of requiring potentially new funding from a budget.

Another piece to think about is the kind of governance model you will have. There is a range from the very centralized—where everybody has to participate in every decision—to a much more delegated approach. As you have more delegation, you need more trust, obviously, between the participants. We looked at types of governance models thinking about what kind of accountability there would be, the flexibility of the structure, both in terms of letting people in and out of the group—easy on- and off-ramps—and flexibility for operations should the communities need to do more or change what they're doing.

I want to note that a traditional idea often is that if you have an interlocal agreement or a memorandum of understanding (MOU), there's a point where people decide if they are signing on or not. However, some groups are willing to have observers so that you keep other entities informed and they are able to more quickly join the process when they're able to later. In this approach, members would join a body akin to a steering committee and non-signatories would be non-voting observers. Depending on the number of participants and each community's resources, a steering committee could choose to develop a working group, made up of a selection of members who might take the lead on implementation.

An approach that we suggested to increase the flexibility of a joint enterprise over time is to allow multiple working plans within the cooperative entity. So, all the coalition members can join, via a MOU or interlocal agreement, but then a subset can decide to participate in the vulnerability assessment and a different subset can go ahead with an infrastructure project. This would allow multiple projects under the umbrella of the coalition (as created by the MOU or interlocal agreement) but not require uniform participation in all undertakings. Building in this flexibility could create more complicated structures but could also save time and resources over the long run by allowing multiple uses of new cooperative arrangements.

The last thing I want to touch on is what it means working with these multijurisdictional clients. I approach this from a legal perspective, but I think a lot of it applies to consultants as well. Some of the biggest issues are confidentiality and conflict, and whether your role is as a problem responder/solver, project facilitator, or instigator. If you're hired to help a group of communities form an entity, who is your client? Is it each individual municipality? Is it the entity that doesn't exist yet because you're going to help create it?

There is something we ran into. We interviewed all the participants in the municipalities and we learned about their histories working with each other. Can you share all that information? Where does the information go if you're the middle person? And if you're there as the problem solver—which is a typical role—and the group says to you, okay, this is what we want you to do, can you go ahead and do that?

If you're a facilitator though, maybe your role is a little different. For example, perhaps you could choose a governance structure if you are concerned that some of the smaller communities or the bigger communities aren't going to have the right level of participation. When do you raise additional concerns like these?

The most extreme version of participation is the instigator role, where you could bring up issues that aren't even on the agenda. You say to the client, this is what you're covering, here's more things you could be working on, and so on. Do you want to add this to the scope of your work? Those are different approaches that can be taken.

Communities working on a joint vulnerability assessment, that's almost the easy example even though it was quite a complex project. Consider, for example, flooding along one of the rivers in the Midwest last year. There again, you have multiple states that need to coordinate on issues like levee management, dam use, where they're allowing new development, and what they're going to do to protect existing development. We've seen the U.S. Army Corps of Engineers has been sued for operating levees and dams, and for not operating them. They're always in a very hard position.

And so, some of the things people are starting to think about is whether we need a model ordinance that multiple

states could adopt or a model enforcement procedure for levee managers. Or there are things like flood easements. If we're going to have flooding, how do we compensate the landowners that we're choosing to flood? How are we prioritizing land uses and accounting for that? For the answers to these questions to have a meaningful positive impact, we may need coordination across jurisdictions.

Rebecca Kihslinger: We do have a number of questions that have been submitted. There's a couple versions of this question. What cities or places do you see as being the best-suited for addressing climate change based both on the natural climate of the area and the mitigation measures the government in the area is taking?

Sarah Kapnick: I talk about science. I don't talk about policy. Scientifically, when we look at these different cities, different cities have different things that they're facing because there are different climates and different types of extremes. Like on the West Coast, you have issues relating to water and water resiliency and wildfire. On the East Coast, there are certain places wildfire exists now, but it's not as much of a concern and water availability isn't a concern. It's more coastal flooding, riverine flooding, and drought in agricultural regions.

So, it really depends on the location about the types of problems they face. That's part of why things like the National Climate Assessment and building data sets that we can use across the United States are so critical. Then we can look at what the extremes are and how they might be changing across the entire country, to try to make these comprehensive decisions or comprehensive assessments about where the risks are and where they're changing.

Edward Kussy: Decisionmaking in the United States is very fragmented. But if you have decisions about buildings and resilience of buildings, that's local government. Transportation is done largely by the states, or by local coalitions, or even a separate local entity. Then, something like whole-area flooding is a mixture of agencies like the Corps and the state government. It's hard to answer that question specifically because it varies so much in the United States. Other countries organize differently. That's not a ubiquitous problem in the world.

Paul Hanle: I'll add something that relates to the project I was talking about, the Climate Judiciary Project. Cases related to impacts of climate change are being brought around the country in both state and federal courts. In fact, they're being brought in many states. So, the things that we look at as far as climate change is concerned, are where are the states where there are impacts that are being adjudicated and how can we help judges to understand the underlying science as well as possible in those cases.

In a way, it connects with the National Climate Assessment and also what Sarah mentioned about those billion-dollar events. That's one way that we look at where there can be a meaningful conversation about climate change.

Rebecca Kihslinger: I think it's really interesting and sort of a broader question than how it's posed here, but would you discuss the role of Atlas 14, which is NOAA's precipitation frequency estimates? And anticipating local flood events and appropriate local stormwater system design, discuss the needs to have that updated more frequently, funded by Congress, and done at a national scale instead of by regions. I think that's a specific question, but maybe also a broader question about appropriate resources allocated to the data and the science needed to make these decisions.

Sarah Kapnick: For people who don't know Atlas 14, I believe it really took off in the 1960s. I actually have an intern working with me on Atlas 14 right now. There are documents; every single state has a table and data that they can use of what are the likelihood of extreme precipitation statistics in the state. Those are based on observations that are available. Some of the states, like Oregon, still have one based on the 1960s or 1970s. Different states have been updating them. Texas updated theirs, I believe, in 2018. And so, they're being updated. It's monitored by the National Weather Service. But these documents, to be able to understand what are the risks of extreme precipitation, are based on observations.

Now, we have all these new sciences and we have climate models so we can start saying things about what risk might be in the future. But that's not part of how Atlas 14 was originally developed. Separately, we have research on how precipitation extremes may be changing. That research keeps evolving as we evolve our models and our techniques. There's now a separation between that research community of extreme precipitation and what it's going to be in the future, versus the Atlas 14 documentation and those tables that are really fundamental to being used for risk planning.

For example, people who are developing sewers look at those tables and say, we want to be resilient to the 100-year risk for one-day, two-day, three-day precipitation values. They build the system with those as an extreme value that they want to be resilient against, but it's based on observational data. There's a question of how to start integrating the new data streams that we have available. And this is specific to extreme precipitation, but there's many different examples that we could find.

Rebecca Kihslinger: I think that relates to this other question about issues facing already overburdened communities that are vulnerable to these impacts from extreme weather and climate change and local governments that might not have the capacity to find, and understand, and be able to apply those data sets. What do you think lawyers, and other advocates, and facilitators, and community groups can do to help those, to support those local governments and communities?

Aladdine Joroff: One thing Massachusetts has done is provided funding for communities in the state to do a vulnerability assessment. Now, these are in a different scale than say Boston or Cambridge has done, which used con-

sultants and had a multi-year process. I think initially by a couple of communities going first and putting a lot of resources in, it may have deterred some smaller towns who didn't have that kind of money from doing that, because they were unsure if they also needed to hire someone to do a kind of downscaled data analysis.

I think another helpful approach is providing road maps and tools for what you can use as proxy information for future impacts. The U.S. Environmental Protection Agency, for example, has had documents that say, you know, assume a 500-year floodplain will be a 100-year floodplain.[46] Is that the most accurate? No. But it's a starting point. Assume anywhere that floods now will flood more if you're not changing your behavior. So, definitely I think that states have been helpful in providing the funding.

They also in Massachusetts train consultants to go and do those projects so there's some consistency across them. But I think the coordination of towns and cities hearing from each other, kind of having model programs or model ordinances out there to look at as a starting point, is very helpful.

Edward Kussy: Transportation is one of the areas that is very heavily funded both by the federal government and the states. Typically, the state transportation department is one of the richer agencies in state government, so the resources are there. There are a lot of demands on any government agency to do what it always has done—build roads, support education, whatever—and focus more and more on resilience or on dealing with the effects of climate change. But (1) it's not simple, and (2) it diverts from the underlying mission that the agency sees itself as doing.

For example, I've always worried about levee building in the Mississippi River because that may protect a particular community, but it effectively passes the danger of flooding downstream. It's very hard to tell a farmer in North Dakota or South Dakota, your land has to be flooded because you want to protect the town 500 miles away. That's unfortunately how river flooding works. It's very hard to tell somebody who has a house on the Outer Banks of North Carolina that when that hurricane comes and does major damage to their house, they're on their own. They can't get any insurance. Those are difficult things to say and, frankly, these acts are political. So, sometimes they're not as consistent and responsive as they should be.

Rebecca Kihslinger: Getting back to your point, Aladdine, about coordination. Because I do a lot of work in hazard mitigation planning, I wonder about how the hazard mitigation planners are integrated into the planners with resilience and vulnerability assessments. Those plans do have a risk assessment and a vulnerability assessment part of it. I'm thinking more about that coordination and how you get not only the communities together, but all these different agencies that are working on these different efforts.

Aladdine Joroff: In an ideal situation, you have coordination across all the agencies. You want your housing department to be working and thinking about climate change at the same time. For example, Boston pushed to have new Federal Emergency Management Agency maps, which like precipitation tables, are a source of data that's often out of date. They got new 100-year flood maps, and it turned out that it increased so much the number of wetlands that now needed to go before their Conservation Commission for review. That commission has to come up with new procedures because it could not process that many applications. That was something that I think they learned after the fact rather than in a broader conversation. It's particularly hard because in Massachusetts those commissions are made up of volunteers.

Edward Kussy: If this pilot program that's been added to the House transportation bill is enacted, that's something you might be interested in following. It's exactly what you were just talking about.

Rebecca Kihslinger: I want to come back to one clarifying question for Sarah, and that's the source of the economic impact data of extreme weather events.

Sarah Kapnick: I used a map that showed the 14 billion-dollar events that occurred in 2019. The National Centers for Environmental Information collects all of that information when each event happens. They have their set of metrics that they publish that you can look into, where you can see the exact methodology of how they collect that information. It has a time span slightly different than what the insurance companies may release, but they generally are getting similar magnitude events.

Rebecca Kihslinger: The next question is for Paul. Are there examples of successful lawsuits stemming from extreme weather linked to climate change?

Paul Hanle: If you ask, are there examples where there have been successful suits brought, the answer is not yet to my knowledge. Usually, many of the cases have stopped at the preliminaries, particularly around standing, for example.

There are several high-profile ones that have not been decided yet, or have been decided against the plaintiffs such as the *Kivalina* case in Alaska.[47] Even more recently, there is a case in New York that deals with fraud and corporate responsibility of the companies that were being sued.[48] Again, the case was thrown out.

46. *See* U.S. EPA, Smart Growth Fixes for Climate Adaptation and Resilience, at iii (2017) (EPA 231-R-17-001) (including adopting the 500-year flood plain as the "locally regulated flood plain" as a planning/mapping tool for addressing flooding and precipitation).

47. Native Vill. of Kivalina v. ExxonMobil Corp., No. C 08-1138 SBA, 39 ELR 20236 (N.D. Cal. Sept. 30, 2009).

48. John Schwartz, *New York Loses Climate Change Fraud Case Against Exxon Mobil*, N.Y. Times, Dec. 10, 2019, https://www.nytimes.com/2019/12/10/climate/exxon-climate-lawsuit-new-york.html.

So, the answer is not so far, but we have asked judges if they think that there will be more cases and whether the question of extreme weather science will come to bear. Many have said they expect there will be.

Edward Kussy: I have a question offhand. Can you attribute the massive settlement of PG&E for the town of Paradise with the Camp Fire? Isn't that how a climate change case is likely to arise, that you have some consequence that might be due to climate change that produces liability?

Paul Hanle: It certainly seems relevant, doesn't it? But I think that the decision on that was built around the fact that they were said to be negligent in their maintenance of the power lines. That may or may not matter in a non-climate change environment but, anyway, it is a relevant fact.

Aladdine Joroff: A lot of the cases where the climate change attribution studies are really relevant are where cities and counties are suing large extraction companies, like the Exxons of the world. Not just Exxon though. And in this area, we haven't had a substantive decision yet because what's been happening is the defendants, the companies, are trying to argue that this should be in federal court (and the U.S. Supreme Court has said that there is no room for federal common-law claims for climate change damages).

So, the plaintiffs are bringing claims that there's a nuisance caused by the emissions from these companies' activities and it's going to cost them money or already has on adaptation measures. They're trying to seek damages. Mostly, those cases we've seen procedurally going back and forth between federal and state court to figure out which court should they be in, with the counties and cities trying to stay in state courts so that it's state-law claims that wouldn't be precluded under federal law. I don't think we have, as Paul said, a substantive decision on it yet. But that's where the science is being used a lot or will be if they proceed.

Edward Kussy: There are a few cases under NEPA, which is an analysis of federal actions. California as well where climate change factors have to be considered, and then challenges are made that they were not considered adequately. So, you have those kinds of liability cases. But they do the litigation with climate change.

Paul Hanle: And some of those actually have gotten to a place where, as you said, you have to go back and deal with the science of climate change.

Edward Kussy: Right. I worked on a case like this long ago. It was 15 or 20 years ago about transportation of coal and the impact that that might have on climate change when massive amounts of coal are under the energy stream.

Rebecca Kihslinger: We did some related work but more looking at the resilience side of things. We worked in San Diego County with the county and then jurisdictions in looking at what their liability might be for implementing adaptation measures or for not doing anything. We rated different kinds of adaptation measures basically for the likelihood that somebody will sue them for implementing those adaptation measures or for not implementing anything and what happens if there's damages as a result. Is that something that's come up in your work, those kinds of cases?

Paul Hanle: It absolutely has. We've done a survey of all the kinds of cases where we worked closely with our friend and advisor, Michael Gerrard, who keeps an online database of this at the Sabin Center for Climate Change Law.[49] Those kinds of cases are certainly a part of the whole picture as well.

I think that, for us, what we were looking at specifically is how the science comes to bear on the cases. There's virtually no examples where that has happened yet. But as Ed points out, it's under regulatory cases. Certainly, climate change is coming to the discussion.

Aladdine Joroff: We worked on a paper with the Conservation Law Foundation where we looked at this question from Massachusetts communities.[50] What we noted is there are not many cases yet about climate change adaptation. But if you look at communities being sued for stormwater management, storm impact, sewer systems overflowing, then that's a really good sample study of the types of cases that could evolve with the climate change impacts.

It will depend state-by-state on their tort protections because a lot of these cases were brought as negligence claims, as nuisance claims, and how much immunity the communities will have in each state will vary. And then getting involved in the nuances of when it's a policy decision versus a maintenance decision. Yes, I think it's something that's coming.

I would flag something else to keep in mind: the idea of passive takings claims. Again, there are not many, if any, that have been successful yet, but the idea is that a community could be sued for taking property by not acting to protect that land. And on another front, there was the example of an insurance company that had sued a bunch of communities in the Chicago area to recover claims that the insurance company had paid to individuals in the area whose property was flooded because of storm impacts.[51] The insurance company actually withdrew the complaint, so we didn't have an argument there, but definitely there's interest from other parties about that kind of cost recovery.

Rebecca Kihslinger: I have one last question that I thought might be a good way to end. Do you think extreme weather is a useful communication tool to illustrate climate change?

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49. Sabin Center for Climate Change Law, *Home Page*, https://climate.law.columbia.edu/ (last visited Nov. 13, 2020).
50. Deanna Moran & Elena Mihaly, Climate Adaptation and Liability: A Legal Primer and Workshop Summary Report (2018), https://www.clf.org/wp-content/uploads/2018/01/GRC_CLF_Report_R8.pdf.
51. Illinois Farmers Ins. Co. v. Metro. Water Reclamation Dist. of Greater Chi., No. 2014CH06608 (Ill. Cir. Ct. filed Apr. 16, 2014).

Maybe especially in places where those discussions are not far along or harder to have.

Paul Hanle: I'd like to answer that from my experience at Climate Central. We thought extreme weather was a powerful way if you could make the link in the minds of the people who were seeing that crazy extreme weather, weird weather let's say, is related to the emissions of greenhouse gases, fossil fuels. I worked closely also with Yale and George Mason University. We did surveys about people's views about climate change—that the extreme weather was one of the manifestations of climate change that was beginning to change public opinion.[52]

If you look at the changes over time of that, you'll see that there's been virtually steady movement to acknowledging climate change. And if associated with extreme weather, it's one of the correlations at this time. Quite a bit of change, by the way. It's at a point where something like 80% of the public acknowledges that it's real and about 60% say that it's got to do with fossil fuels.[53] We correlate that to people seeing extreme weather events.

Sarah Kapnick: I would argue that some people are very afraid of the extreme weather. No matter where they are, they hear about changes in extreme weather that's happening elsewhere. It forces them to want to change and alter their behavior. But we also have other people who are only reacting to what they're experiencing. Therefore, for them, with certain types of climate change studies, the research really needs to be local. It needs to be problems that people face in the communities that they're in.

I work with scientists internationally and I work with scientists in Africa. If you talk to certain scientists in Africa, they're saying, "We don't care about extreme changes in the United States. We have our own—we're worried about famine. We're worried about the availability of water and agriculture, and the effect on our ability to have tourism because that's our major industry—and biodiversity." So, it depends on where you are. Even in the United States, I would say a diversity of thought around the science of climate change is critical to getting people to understand climate change and the issues.

One of my postdoctoral researchers, Karin van der Wiel, works with me on that Louisiana study that Paul mentioned, and we also did a study of something called "mild weather." That would be the weather that you want to have a barbecue outside, or you want to have a soccer game, or you want to go on a nice stroll. It's not raining. It's not too hot. It's not too cold. It's not humid. The study shows that mild weather days are dramatically declining. They've already declined by several days per year where you live. They're going to decline more rapidly during the course of the next century.

When that study came out, we had 100-something media interviews on that study. It was widely reported and many people responded to that study. It was the absence of extreme. It was average weather. Average weather that you like, that you enjoy. People relate to that because some people can relate better to the weather that they more regularly experience than to the extremes that mainly happen once every two years. So, I think it depends.

Aladdine Joroff: I was going to second what Sarah was saying. I think that the localized messaging really matters. Like the sunny-day flooding in Florida, I think, gets more attention than the potential sea-level rise. Just as an example, the vulnerability assessments that communities do in Massachusetts, they have stakeholder meetings. In one coastal community, they ranked their biggest concern as wildfire from the impacts of climate change, which is not usually a concern in Massachusetts. But this community had a forest fire in the 1970s and there are enough people who still live there who remember it. When they think natural disaster, that was their biggest concern.

So messaging to them about sea-level rise, seeing that they're on the coast, wasn't necessarily going to get their attention. At the same time, you're going to have to take their input and figure out how you spend your resources, probably not planning against another potential wildfire, but still addressing their concerns.

Edward Kussy: I think part of this problem is not scientific but political. I don't mean what the president says or doesn't say, but the whole politics of climate change. I think it sounds kind of complicated and sounds distant. But when events happen either where you live or very close by, it's important for advocates that are worried about this issue to take that as an opportunity to explain what's going on in terms that mean something because it's the place where you're at.

We have all the science. All the scientists say this. I agree with all that. I worry about that. But a lot of people worry on a much more focused thing. I think making this real and understandable is a very important part of convincing people to worry about this stuff.

52. Kate Richard, *Connecting the Dots Between Extreme Weather and a Changing Climate*, Yale Program on Climate Change Communication, Oct. 4, 2018, https://climatecommunication.yale.edu/news-events/connecting-the-dots-between-extreme-weather-and-a-changing-climate/.
53. Yale Program on Climate Change Communication, *Home Page*, https://climatecommunication.yale.edu/ (last visited Nov. 13, 2020).