ANL-21/26

Argonne NATIONAL LABORATORY

AMERICA RESILIENT

CLIMATE CONFERENCE

APRIL 14, 2021

U.S. DEPARTMENT OF ENERGY

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America Resilient Climate Conference

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July 19, 2021

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EXECUTIVE SUMMARY

On April 14, 2021, scientists, policymakers, and other interested parties from research institutes, academia, and other organizations gathered together virtually at the America Resilient Climate Conference to discuss one of the most pressing challenges of the 21st century: building resilience to climate change.

Climate change affects the security and health of all Americans. Coastal areas are enduring more frequent and severe flooding due to sea level rise and storm surge; western states and Alaska have experienced increasingly devastating wildfires, driven in part by hotter, drier, and longer fire seasons; and communities across the nation have suffered through extreme precipitation events and heat waves (Figure 1).

Even if emissions are reduced aggressively in the near future, the world—and the United States—will continue to feel the impacts of climate change for decades to come, due to the continued accumulation of greenhouse gass in the atmosphere. Consequently, it is essential to act now to protect natural and human assets from the gradual—as well as extreme—impacts of a changing climate.

To build resilient communities, leaders and community members need science-based information about the potential impacts climate change will have decades into the future and for specific regions. Therefore, it is essential to develop high-resolution climate models that can project both various climate impacts and the interactions between earth system variables and humans down to regional and local scales. Collecting and curating data for such models and their computational requirements poses large challenges. In the future, artificial intelligence will be needed to increase their accuracy and reduce associated uncertainties. The investments in Earth system science and artificial intelligence made by the U.S. Department of Energy and other federal entities will be essential in addressing these challenges.

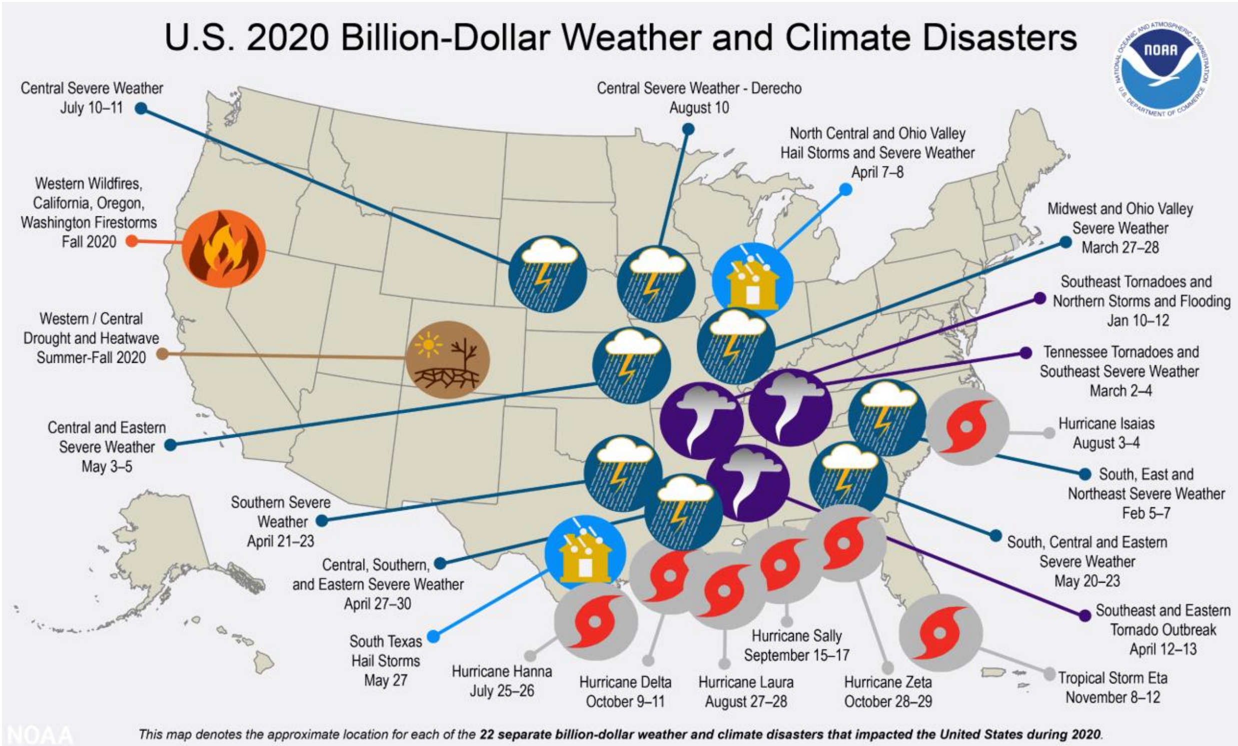

Figure 1: Billion-Dollar Weather and Climate Disasters in 2020 (courtesy of NOAA[1])

[1] For more information, see: https://www.noaa.gov/stories/record-number-of-billion-dollar-disasters-struck-us-in-2020.

Detailed projections from high-resolution climate models are critical to informing adaptation and resilience efforts across scales. Incorporating them into decision science models, risk and vulnerability assessments, and visualization tools enables science-driven adaptation to extreme weather and novel approaches to infrastructure retrofitting, maintenance, and comprehensive redesign. This integration can also aid in planning and preparing for the future by helping rethink urban and regional planning; design systems that can adapt to evolving environmental conditions; and thereby meet the requirements of future generations.

Climate resilience is the ability to anticipate, prepare for, withstand or absorb, and ultimately respond to climate change impacts such as extreme weather events, as well as gradually increasing temperature and altered water availability. Building climate resilience involves assessing immediate and future climate-related risks and taking steps to better cope with these risks. Key challenges in building resilience are the widespread lack of climate-related expertise among decision-makers and the diverse range of stakeholder needs and domain areas. It is imperative to increase climate change-related education and traning for stakeholders and decision-makers and democratize access to translated existing decision-relevant climate information.

Removing barriers to information access will enable decision-makers in all regions and communities to focus their resources on adaptation and resilience. It will also go a long way toward addressing environmental injustice issues that specific communities face in the United States. Currently, some groups encounter greater risks from climate change due to their location, their income, and their limited access to healthcare and other resources. In the United States, these more vulnerable communities often consist largely of people of color.

Because the current energy and environmental system remains, in this sense, unjust, and climate change may exacerbate current inequities, it will be important to ensure that responses do not harden existing injustices. Instead, we must use this opportunity to address longstanding inequities when building resilience.

> "I would ask all of you, as you think about resilience and about hardening infrastructure, 'What are you hardening and cementing in place? Inequality?'"
>
> *— Shalanda H. Baker, Secretary's Advisor on Equity, DOE*

PERSPECTIVES FROM KEYNOTE SPEAKERS

> "When we are thinking about climate justice, we're thinking about resilience, the topic of this conference. We need to ensure that the energy system of the future does not leave communities of color in the dark. We also have to think about how policy can inform the choices that grid operators are making with respect to what assets are being deemed important enough to save in the event of a major climate event."
>
> — *Shalanda H. Baker, Secretary's Advisor on Equity, DOE*

Three representatives from the federal government presented keynote speeches at the conference. Shalanda H. Baker, first-ever Deputy Director for Energy Justice and Secretary's Advisor on Equity, U.S. Department of Energy (DOE), kicked off the meeting with a reminder that societal resilience should be built in a just and equitable way to meet the needs of all people and communities. Baker discussed the presidential Justice40 Initiative, which promises that 40% of the overall benefits of certain federal investments will "flow to disadvantaged communities […] in the areas of clean energy and energy efficiency; clean transit; affordable and sustainable housing; training and workforce development; the remediation and reduction of legacy pollution; and the development of critical clean water infrastructure."[2]

Baker discussed how the development of our current energy system has been one of the root causes of the energy access, environmental, and climate change injustices faced by communities of color and argued that the 2020 national reckoning on race and justice must extend to addressing the social consequence of climate change. She explained that building resilience will require energy policy changes to lighten the burdens currently shouldered by communities of color.

"I would ask all of you, as you think about resilience and about hardening infrastructure, 'What are you hardening and cementing in place? Inequality?'" Baker said. "Or are you cementing in place something that creates a deep and lasting community resilience?" Baker's parting remarks called to leverage a crisis such as that of climate change to create a system that no longer places people of color on the frontlines of climate change and to build resilience for all communities in the United States.

> "All of us as human beings who understand the science, we recognize the gap between what's necessary and what's possible—and all of us who are rowing in the same direction appreciate the need to close that gap."
>
> — *Sean Casten, U.S. Representative*

Speaker Sean Casten, U.S. Representative and member of the House Select Committee on the Climate Crisis, discussed the committee's roadmap to address the climate crisis, which includes drastically reducing carbon emissions and harnessing research and development to decarbonize industry.

Casten, who also serves on the Financial Services Committee, outlined the committee's efforts to support and reward new technologies and business models that will expedite a clean energy economy. He highlighted the role of the private sector, as well as federal research, in achieving the transition. "We need to look across all of our committees and be fully ballistic

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[2] For more information, see https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/27/executive-order-on-tackling-the-climate-crisis-at-home-and-abroad/.

about addressing climate change," he said, "and we need to recognize that doing so is an economic and environmental win-win." He also proposed to develop a roadmap for decarbonization and resilience across all the responsibilities that are currently dispersed among different government committees and organizations.

U.S. Secretary of Energy Jennifer Granholm closed the conference by recapping the importance of building climate change resilience. Society will continue to experience extreme weather events and the gradual trends of increasing temperature and decreasing water availability due to climate change, she said. The amount of carbon currently in the atmosphere will mean that those changes will be experienced throughout the decades to come. "So, we need to work to make our communities and our country more resilient to the impacts of climate change," she noted.

Research and industry efforts—such as those geared to supply the local, actionable data outlined at the conference—are encouraging. Granholm made a strong case for the role of science, scientific collaboration, and the science investments provided by DOE in broadening our toolbox to address resilience. She said, "These once-in-a-century storms are going to keep coming, but not all of them need to be crises. With our increasingly better knowledge we can look ahead and see what the future has in store for us, and we can use that powerful information to adapt and grow more resilient."

> "While it's critical that we decarbonize our economy as quickly as possible, the fact is the emissions we've produced have already baked in weather patterns that are going to still unfold over years to come […] These once-in-a-century storms are going to keep coming, but not all of them need to be crises."
>
> — *Jennifer Granholm, U.S. Secretary of Energy*

INTRODUCTION

The impacts of ongoing global climate change are increasingly being felt across the United States. Extreme weather events are becoming more frequent and more intense; temperatures are rising; drought and heat waves are expanding; and sea levels continue to rise. A record number of billion-dollar disasters struck in 2020 (Figure 2), causing a significant loss of lives and property and totaling more than $95 billion in damages.

Scientists and policy leaders around the world have been urging cuts to greenhouse gas pollution and advancing the adoption of clean energy and technology. However, because of the greenhouse gases that have already been released into the atmosphere, even if emissions are quickly reduced, the world—and the United States—will continue to feel the impacts of climate change for decades to come. In order to mitigate the degree of likely human suffering, loss of biodiversity, and the potential for wide-ranging disruptions to critical societal systems and functions, it is essential to act now to protect both natural and human assets.

> "It's important to recognize that climate change is affecting all of us. It's affecting all the United States and all regions of the world, and it's affecting all sectors of our society, whether we're talking about health, transportation, agriculture, water resources, or energy."
>
> — *Paul Kearns, Director of Argonne National Laboratory*

In 2015, the Paris Climate Agreement included, for the first time, a global adaptation goal. Many countries, states, and cities are now developing and implementing climate adaptation plans and actively reducing their carbon emissions. Adaptation in this context refers to adjustments in technological, ecological, social, and/or economic systems in response to actual or expected impacts of climate change. Climate change adaptation helps individuals, communities, organizations, and natural systems to deal with the consequences of climate change that cannot be avoided. It involves taking practical actions to create adaptive change and build resilience.

Climate resilience derives from the ability to adapt to change . It requires the ability to anticipate, prepare for, withstand or absorb, and respond to hazardous events, trends, or disturbances related to climate. Improving climate resilience involves assessing how climate change will create new—or alter current—climate-related risks, and taking steps to better cope with these risks. To facilitate building climate resilience at a national and community level, Argonne National Laboratory hosted the America Resilient Climate Conference on April 14, 2021.

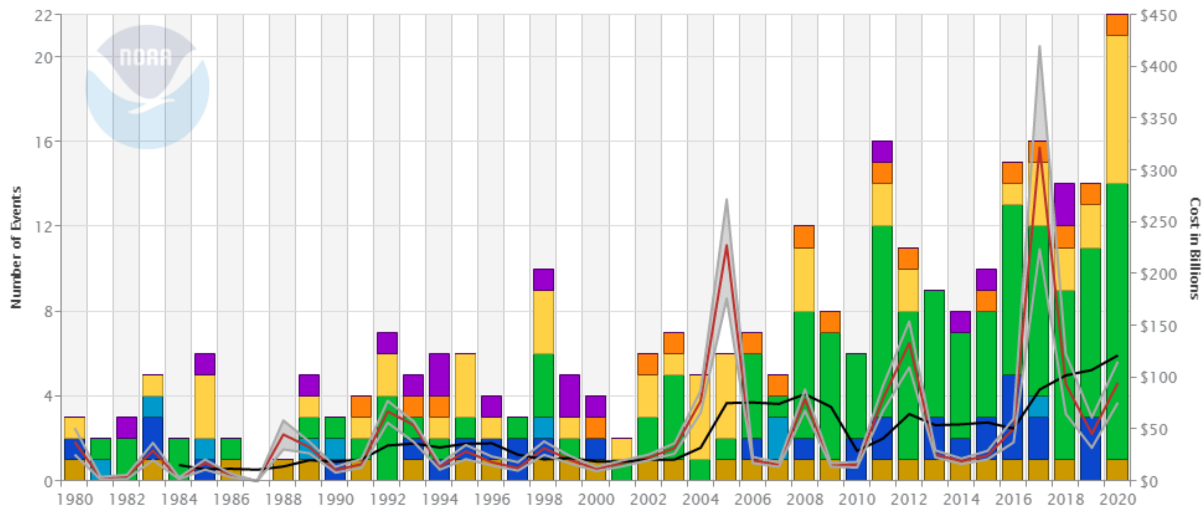

Figure 2: U.S. Billion-Dollar Weather and Climate Events, 1980–2020 (courtesy of NOAA)

Successful adaptation and resilience efforts depend on the active, sustained collaborative engagement of policymakers, scientists, industry, government representatives, and community members, and a strong emphasis on science and data to inform viable paths forward. This process must engage stakeholders across various regions and sectors, and at various levels. Discussions during this conference focused on key themes necessary to build resilience into the future in the United States. Themes included:

- High-accuracy, high-resolution climate models with an appropriate level of uncertainty are needed to project potential climate impacts at the regional and local level. The findings of these models must be analyzed and translated into understandable and actionable information that national, regional, and community decision-makers can use.
- Environmental justice and equities in the most vulnerable communities must be built into research programs and new systems put in place to promote climate resilience.
- Better data and tools are required to help governments and industries take proactive, effective steps toward building resilience.

This report summarizes key discussions from the panels and keynote speakers. The conference participants hope that it will serve as a resource for coordinating research, industry, government, and community efforts in planning for—and facilitating—climate resilience in the United States, and potentially elsewhere in the world.

HIGH-RESOLUTION CLIMATE MODELS

Climate change and related more-extreme weather affect all sectors of society, from human health to transportation, agriculture, water availability, and infrastructure. Although the nation is taking action to decarbonize its energy systems, parallel efforts are needed to reduce the adverse impacts of climate change in the coming decades.

To build resilient communities, leaders and community members need information about the potential impacts of climate change decades into the future. Global earth system models typically provide high-level (100-km^2) resolution information on projected changes in temperature, precipitation, or the availability of resources. However, many human and socioeconomic factors can vary vastly within a 100-km^2 area, and for climate models to provide value to communities, they must deliver highly accurate data for individual regions and cities.

The Changing Climate: What Should We Do?

There are three options:

- **Mitigation:** measures to reduce the pace and magnitude of the changes in climate.
- **Adaptation:** measures to reduce the adverse impacts on human well-being resulting from climate change.
- **Suffering:** the adverse impacts and societal disruption not avoided by mitigation or adaptation.

We need enough mitigation to avoid the unmanageable, and enough adaptation to manage the unavoidable.

— *Donald J. Wuebbles*

Several projects are currently underway to generate the spatial resolutions needed for such high-resolution climate models. One of these, the DOE Energy Exascale Earth System Model (E3SM), optimizes powerful DOE high-performance computational facilities to model, simulate, and predict Earth systems. It targets achieving spatial resolutions of 25 km or less, thereby improving model fidelity and spatial specificity. High-resolution modeling also allows human–Earth system interactions to be better represented. The data that high-resolution models provide can be used to evaluate how climate change affects energy security and to understand the implications of societal responses to climate change.

Researchers like Katherine Hayhoe and Donald Wuebbles are developing and evaluating empirical statistical downscaling analyses and models for future scenarios. They and Argonne researchers like Rao Kotamarthi use non-hydrostatic physics-based downscaling models ("dynamic downscaling") to translate information from large scales to the spatial and temporal scales needed to assess local and regional climate impacts, vulnerability, risk, and resilience. Their simulations examine how climate change influences key physical processes and how it impacts severe weather and water resources throughout North America.

Current Challenges

Capturing human–Earth interactions requires data from a wide range of scales, from local to global; a single scale cannot capture all such complex dynamics. Human and socioeconomic systems are less well understood and predictable than the physics of temperature and precipitation. On the other hand, many new data opportunities are arising as a consequence of pervasive information and communication technologies. Collecting and making sense of such data remains challenging and requires an interdisciplinary approach.

Because climate effects tend to be local, predicting their impacts requires fine-resolution models. These models need to capture the low-probability but high-impact events that can cause extensive damage. Developing accurate models that can predict the regional impacts of climate change will be a significant challenge, and the observational data required to calibrate, test, and run these models is sparse.

On the human side, the decision-makers who most need the information produced by models are not necessarily equipped to understand their technical outputs. Simulation results must be translated into meaningful and actionable data for non-modelers and non-scientific users.

Computational requirements for ultra-high resolution climate simulations (decade-to-century long) at global scales remain prohibitive, even on exascale computers, so new strategies are needed for using these models. Ultra-high-resolution modeling may require hybrid central processing units–graphics processing unit (CPU-GPU) computing platforms. This will introduce new challenges to the research community, which will need to adapt to new coding protocols. Limited-area climate models are less computationally expensive, but they still require large amounts of computation time, cannot produce a large number of ensembles for uncertainty quantification, and are unsuitable for century-scale simulations. Kilometer-scale models can only simulate a year or two, because they require such small timesteps.

Addressing the Challenges

Developing useful models that generate actionable data will require researchers to define the risks and vulnerabilities from a rapidly changing climate and to identify potential impacts. The next step is to determine appropriate solutions that address those vulnerabilities in the context of other societal and environmental issues.

Ultra-high resolution models will help in this effort by better representing human–natural system interactions. However, it is still important to include models with different complexities and resolutions to support diverse uses. New advances in computing, including artificial intelligence, also hold great potential to revolutionize climate modeling.

Several avenues exist to translate model findings so that they are useful to stakeholders. Ideally, this will involve building rapport between stakeholders and the climate experts who are familiar with the models. One approach is to convey global climate models as a "synthetic Earth" that can be run into the future, where the output can be used much like a weather forecast to predict impacts.

Figure 3: Downed Power Lines in Puerto Rico after Hurricane Maria (photograph by Jane Palmer)

Another approach is to characterize the uncertainties from the physical process and the efforts to improve them. In this case, research and scientific challenges should be addressed concurrently. Scientists need to communicate which modeling results are well understood and mechanistically supported by theories, and which are still exploratory due to insufficient understanding or large uncertainties. High-resolution simulations based on a single model or a small number of models should be presented with caution; high spatial specificity is not equivalent to high fidelity. A critical challenge will be using either regional refinement or uniform grid refinement to develop capabilities to perform multi-physics, multi-ensemble, and multidecadal simulation at high resolutions.

National Priorities

> High-resolution modeling is supported by advances in multiple fronts, particularly numerical methods. We can use regional refinement to allow high resolution to be used where it's needed the most.
>
> — *L. Ruby Leung*

Societal impacts and interactions must be key considerations in following the science of high-resolution models along the path to any solutions. In the United States and beyond, climate impacts often disproportionately affect low-income communities and communities where people of color predominate. These issues of environmental and socioeconomic (in)justice and (in)equity tend to play out at the neighborhood scale, within mere kilometers. Creating climate change scenarios at this scale requires downscaling methods—from high-resolution models to characteristics of the local environment that may differ from place to place, such as the nature of paving and building materials, building age and climate control, tree cover, and anthropogenic heat sources. Data on all these issues is becoming more available at high spatial resolutions, especially from remote and aerial sensing.

High-resolution models are a significant tool for understanding—and thereby addressing—environmental justice at local and regional scales. Without high-resolution climate projections, it is difficult to resolve the differential effects of projected changes on various communities. The modeling scenarios chosen can inform scientists and policymakers about what mitigation and adaptation can be achieved.

The high-resolution projections Katherine Hayhoe[3] developed for the state of California more than 15 years ago were used in a study to understand how increases in extreme summer heat disproportionately affect Black and Hispanic low-income workers who work outside. This study was later cited in the gubernatorial executive order that made California the first state in the nation with mandatory greenhouse gas emissions targets.

Many models may present “imperfect” information with a high degree of uncertainty, but their findings can still be useful as long as the uncertainties are known. Stakeholders are used to making decisions with imperfect knowledge of the future. It is essential to accurately convey sources of uncertainty in predicted climate models and scenarios, but these factors are not deal-breakers in real-world decision-making. In the future, as researchers reduce model uncertainties, the improved models can help users plan increasingly cost-effective and refined actions.

[3] See https://www.pnas.org/content/101/34/12422.short

ENVIRONMENTAL JUSTICE

Climate change presents a threat to human health and well-being across the United States, along with raising fears of water, food, and critical infrastructure insecurity. However, some groups face greater risks due to their location, health status, access to information, income, and access to other resources. In the United States, these more vulnerable communities are often spatially segregated (especially at the neighborhood level) and consist disproportionately of minority groups, especially African Americans, Hispanics, and Native Americans.

> "One in three households in the United States have experienced some form of energy insecurity, such as lacking reliable access to uninterrupted energy sources at an affordable price. Certain communities fare worse: 45% of Latinx households, 52% of Black households, and 61% of Native American or Alaska Native households have reported experiencing energy insecurity."
>
> U.S. Energy Information Administration: https://www.eia.gov/consumption/residential/data/2015/hc/php/hc11.1.php

Successfully battling climate change and fostering resilience in the decades to come will require recognition of the climate and environmental injustices that currently persist in the United States and strategies that compensate for them with effective mitigation interventions. These goals will also require addressing the tightly related, ongoing energy justice issues that play out across the country in towns, neighborhoods, and households. One in three households in the United States has experienced some form of energy insecurity.[4] Black, Latinx, and Indigenous people are also more likely to live in locations that have many other negative compounding factors—such as those from the toxic byproducts of fossil-fuel energy production—that together cause significant adverse health impacts.

Climate resilience is the ability to anticipate, prepare for, withstand, absorb, and respond to climate change impacts, from extreme weather events to the gradual trends of increasing temperature, flooding, and other disasters. The process of building climate resilience involves assessing immediate and future climate-related risks and taking steps to better cope with these risks. Because the current energy and environmental system is unjust, and climate change only serves to exacerbate current inequities, it will be important to ensure that we do not harden injustices but that we leverage the opportunity to address these long-standing inequities when building resilience.

Fostering resilience and protecting the entire nation against the impacts of climate change will require the development of an equitable energy system. Attention must be paid to the impact of climate on diverse communities: a new approach that aims to give all communities the tools to cope with a changing climate; an energy system that is more accessible, affordable, clean, and democratically managed for all communities; and a way that remediates the social, economic, and health burdens on communities that have been harmed by historic neglect.

> "Tragically we have many of these populations located in parts of our nation and the rest of the world that are much more likely to be impacted by the challenges from climate. People who live on the Gulf, peple who live for a variety of reasons up and down where dams are, or in toxic communities.."
>
> — *Georges C. Benjamin, MD*

[4] For more information, see https://www.eia.gov/todayinenergy/detail.php?id=37072

Addressing resilience and environmental justice requires multidisciplinary and multi-sector action. It is important to have representatives from all sectors—such as environment, health, infrastructure, and economics—at the table with an all-hands effort that includes government, research, and the private sector. When redesigning communities for resilience, there is a need for community consensus on priorities and more stakeholder engagement. Ultimately, the battle for resilience will be fought on a community-by-community basis; but, moving forward, it is important that scientific research and development help build back better in a way that is just and equitable.

Science can play a key role in aiding the mission to boost resilience against climate change impacts and to develop a fairer energy system and environmental remediation. The push toward high-accuracy, high-resolution climate models will facilitate the prediction of climate impacts on health and vital resources at regional and community-specific levels, giving communities the opportunity to help create the tools they need to prepare and adapt and identify the kinds of jobs that will be needed.

DECISIONS ABOUT ADAPTATION AND RESILIENCE

The ever-improving climate projections produced by high-resolution climate models have enormous potential to inform tactical and strategic approaches to adaptation and resilience. Decision-makers at all levels and sectors of government and the private sector need to translate, apply, and incorporate climate projections into decision science models, risk and vulnerability assessments, and visualization tools to inform adaptations to extreme weather events and novel approaches to resilience. Conversely, information also needs to flow in the reverse direction, enabling modelers to understand which events are more relevant to human lives and well-being. Comprehensively incorporating climate projections into decision-making can aid in planning and preparing for the future, meeting the needs of future generations, and rethinking urban and regional planning strategies to design systems that best adapt to evolving environments.

Current Challenges

The primary challenge to optimized adaptation and enhanced resilience is the inability to effectively, rapidly, and scalably translate world-class climate projections into risk-informed decisions. These decisions—if effectively informed and supported by the application of cutting-edge climate projections—can proactively support adaptation of physical and natural infrastructure to climate change, including the protection of natural resources. This goal is complicated by myriad barriers that infrastructure owners and operators, and federal, state, local, and business leaders face in improving climate resilience.

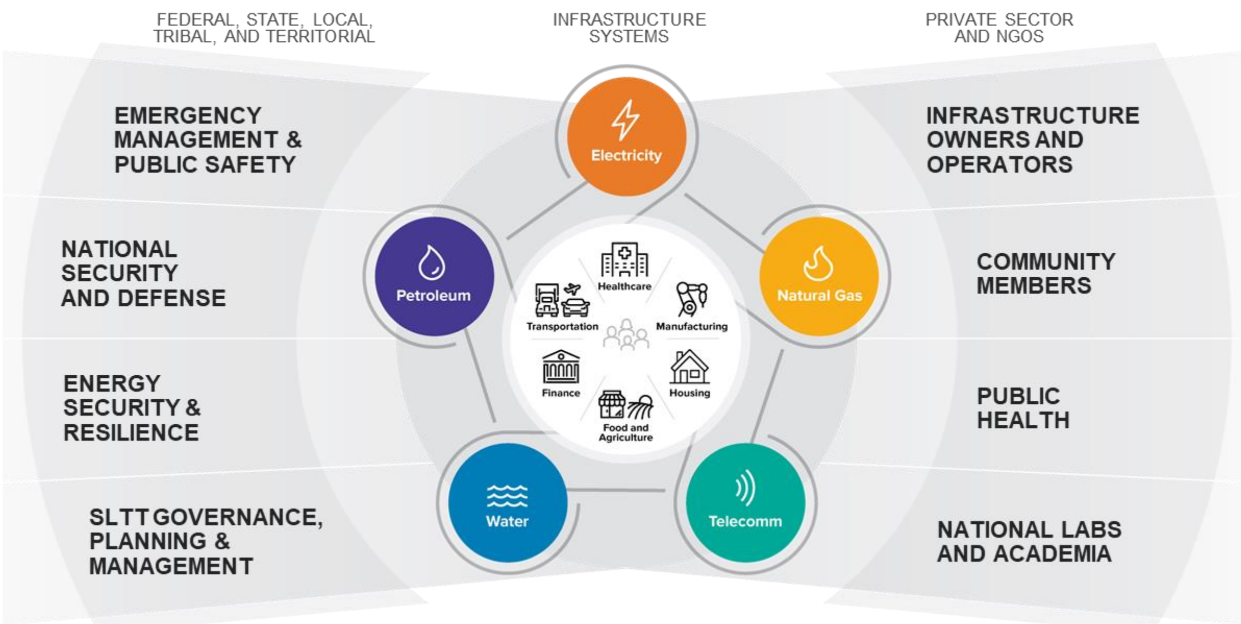

Figure 4: Stakeholders Requiring Translated Climate Projections to Inform Decisions on Economic Security and Resilience (courtesy of: Rao Kotamarthi)

Alice Hill highlighted the persistent, widespread lack of climate-related expertise among leaders and stakeholders who are attempting to make informed, data-driven decisions about adaptation. She cited a 2018 study by New York University's Stern Center for Sustainable Business, which found that, of the 1,188 directors at 100 of the biggest U.S. companies, only 6% had "relevant credentials" in environmental protection, and only 0.3% had expertise in either climate- or water-related issues.

The extremely large and diverse range of leaders and stakeholders responsible for making adaptation-related decisions prevents the application of a "one-size-fits-all" solution to translating climate projections into decisions. (Figure 4 depicts the complex set of stakeholders with critical resilience-related requirements associated with built infrastructure systems.) For example, priorities and tradeoffs (risk appetite, costs, timelines, etc.) can vary significantly between infrastructure owners and operators and emergency managers at the community, city, state, and federal levels. As described by Jennifer Jurado, communities struggle to consistently integrate data and information across highly diverse infrastructure. Climate change impacts and adaptations for resilience do not adhere to jurisdictional boundaries, but that is how decisions are currently being made at the local level.

High-resolution climate projections must be locality-specific in order to translate climate data into asset- or system-level infrastructure decisions. However, barriers to accessing that data currently exist, further deepening inequities for some communities. Access to this data alone is not enough because data does not equal decisions. Leaders and decision-makers are overwhelmingly seeking clear guidance, data specifically contextualized to their needs (e.g., building a business case for monetary investments), and tools to enable their decisions; they are not just seeking data. Further, applied science solutions to enable more immediate climate adaptation actions for infrastructure and the built environment are not yet widely available to those who need it most.

However, while these challenges exist, leaders do not need to wait to take adaptation actions for increasing climate resilience. Although future advances in research and reductions in barriers will continue to enhance the fidelity of climate adaptation decisions, high-quality climate models, local-scale climate projection data for the whole of North America, and infrastructure risk and vulnerability assessment and decision tools are already available today for use across all sectors.

Addressing the Challenges

The first major goal to address this challenge is to democratize access to translated climate data for decision-makers. This includes access to both existing climate datasets and newly generated decision-relevant climate information that more readily translates to stakeholder applications and usefully informs real-world decisions. Removing barriers to relevant and actionable information will enable communities and organizations to focus their resources on actions. Ready access to data will also address critical socio-environmental equity issues. Communities, regardless of resources, should never be hindered by lack of access to the data they need to inform action or help ensure their future security.

The second major goal is to expand decision science to better support climate resilience. Readily accessible information about climate impacts is only useful if decision-makers—many of whom are inexperienced with climate concerns and the nature of climate data—understand how best to apply that information to their specific needs.

A third major goal is to build on existing partnerships between national laboratories and federal sponsors to enhance technical assistance, where researchers work with end-users to apply climate data to their specific decisions. These collaborations provide a vital service in effectively transferring laboratory-caliber science to solve national, regional, and local problems. Communication from communities will, in turn, help national laboratories and other researchers better direct science to align with future uses of their data.

National Priorities

A comprehensive, dynamic, and multi-layered strategy must be deployed to revolutionize approaches to climate change adaptation and resilience. Longer-term climate change mitigation and adaptation must be complemented with immediate (and ongoing) support for climate adaptation and resilience decisions made every day in communities, governments, and private-sector organizations.

Focused, intentional expansion of climate change education for leaders and the upcoming workforce is critical. The climate-related knowledge and expertise gap that Hill highlighted must be addressed so that baseline climate knowledge is incorporated into all relevant adaptation and resilience decisions.

It is also critical to accelerate the application of existing climate resources and tools while longer-term investments increase fidelity and reduce uncertainty. We must democratize access to translated, decision-relevant climate data by making it publicly available. Removing barriers to information access will enable educated decision-makers in all regions and communities to focus their resources on enabling actions, including those that advance environmental justice.

PLANNING FOR THE FUTURE

The faster the world—and the United States—moves to cut carbon emissions, the less adaptation will be required to mitigate the effects of climate change. However, the harsh reality is that all countries and communities will need to make trade-off decisions on potential adaptation strategies, and then implement those strategies to increase resilience for decades to come. Therefore, recommendations for the future align along two related tracks: (1) enabling immediate adaptation decisions using existing science, and (2) continually advancing the science, data, and models to better and more quickly support climate-resilience adaptations.

Key Recommendations:

- Government, private sector, and community decision-makers should not wait for improvements in climate and decision science, data, and methodologies to take action.
- Access to translated climate projection data—and other types of data—needs to be significantly expanded to accelerate adaptation decisions and actions.
- Climate equity considerations should be incorporated into datasets and their applications.
- Scientists need to focus on improving the accuracy of their high-resolution climate models and reducing uncertainties.
- Decision science needs to be expanded and made more available to those who need it most.
- Integration of the human element into high-resolution climate models is vital.
- Early and regular stakeholder integration and input are critical to ultimately making higher-quality adaptation decisions.

Governmental, private sector, and community decision-makers should not wait for improvements in climate and decision science, data, and methodologies to take action. Excellent downscaled climate model results, infrastructure risk assessment models, and adaption decision tools are already available and being used to address some climate change impacts. Although future research advances will focus on improving these models and expanding them to even more impacts, they are often already developed enough to make high-quality decisions in the meantime.

Access to translated climate projection data—and other types of data—needs to be significantly expanded to accelerate those adaptation decisions and actions. Local-scale projections of how climate will evolve in the future are critical for decision-makers to assess risk and make informed decisions (e.g., those involved in investment, planning). Removing barriers to data access will enhance climate equities and enable communities and organizations to focus their resources on proactive actions to increase local and regional climate resilience.

Scientists need to focus on improving the accuracy of their high-resolution climate models and reducing the uncertainties that exist at these scales. High-resolution models will prove essential for producing the local-scale climate projection data (e.g., rainfall, soil moisture, wind) required for analyzing local hazard risks (e.g., flooding, wildfires), and for subsequently assessing associated infrastructure risk and vulnerabilities and adaptation decisions, such as infrastructure asset and system retrofitting or redesign. But as scientists work to increase resolution from 12 km to 4 km (or even 1 km) to enable more localized analyses, uncertainties in the data will increase in parallel. Three methods currently exist for producing high-resolution projections: (1) using global-scale models for regional grid refinement, (2) running global models at high resolutions across the entire globe, and (3) using statistical downscaling techniques. Challenges exist for all three methodologies. The best path forward will involve the convergence of these techniques and, consequently, the development of a holistic approach to using modelling datasets.

Decision science needs to be further expanded and made more available to those who need it most. Readily accessible climate projection data is only useful if decision-makers—many of whom may be inexperienced with climate concerns and data—have the means to understand and apply that data in the context of the risk-informed decisions they are attempting to make. Decision-makers across sectors are highly motivated to improve organizational and community resilience by acting on climate change, but they are not always clear on how best to interpret or apply climate projection data for this purpose. The models, tools, and methods for applying this data are currently not widely available.

Integration of the human element into high-resolution climate models will be vital. This will involve both humans' ability to influence risks (e.g., increasing pace of decarbonization) and the ways in which climate change influences anthropogenic factors in projections. Artificial intelligence will be essential for navigating and interpreting the highly complex and nuanced data simulations that result from climate models, predicting human dynamics, and addressing uncertainty.

> "Let's tap this great American ingenuity that has delivered the world's most incredible technological breakthroughs. Let's show the world that even against a challenge as great as climate change, we can adapt, we can grow more resilient, and we can thrive."
>
> — *Jennifer Granholm, U.S. Secretary of Energy*

Early and regular stakeholder integration and input is critical to ultimately making higher-quality adaptation decisions and plans. Stakeholder input is critical at the very start and throughout the process, so that it is incorporated into the questions being asked, the data being collected and modeled, and the answers and solutions being formed.

Climate equity considerations should be incorporated into datasets and their applications. Historical and current social injustices have led to some population segments being more vulnerable to the impacts of climate change. It is important that adaptation strategies account for, and focus attention on, the most vulnerable sectors of society and avoid the hardening in place of unjust systems.

APPENDIX A: AGENDA

America Resilient: Projecting and Preparing for the Effects of Climate Change—A virtual climate conference convened by Argonne National Laboratory on April 14, 2021.

Agenda

8:00 AM Welcome and Opening Remarks
Paul Kearns, Director, Argonne National Laboratory

Juan de Pablo, Vice President for National Laboratories, Science, Strategy, Innovation and Global Initiatives and Liew Family Professor in Molecular Engineering, University of Chicago; Senior Scientist, Argonne National Laboratory

8:10 AM Keynote
Justice40 and Energy Justice: A Transformative Vision for the Department of Energy
Shalanda H. Baker, Deputy Director for Energy Justice & Secretary's Advisor on Equity, U.S. Department of Energy

8:40 AM Panel Discussion
Equipping Local and Regional Communities to Act: The Path to High-Resolution Climate Models Informing Adaptation Strategies
To build resilient communities, leaders and community members need information about the potential impacts of climate change decades in the future. This discussion will focus on high-resolution climate projections and how they guide the development of local actions and strategies optimized to minimize climate impacts. Speakers will also discuss the need for two-way communication between researchers and community members to enable science-driven solutions for communities' biggest challenges, and the path toward cutting-edge science providing the best possible guidance to stakeholders as they invest in climate resilience.

Speakers

- George Crabtree, Director, Joint Center for Energy Storage Research, Senior Scientist and Distinguished Fellow, Argonne National Laboratory, and Distinguished Professor of Physics, Electrical and Mechanical Engineering, University of Illinois at Chicago
- Kristie Ebi, Professor of Global Health, University of Washington
- Gary Geernaert, Director, Earth and Environmental Systems Sciences Division, Office of Biological and Environmental Research, U.S. Department of Energy
- Katharine Hayhoe, Chief Scientist, The Nature Conservancy and Distinguished Professor and Chair, Texas Tech University
- Donald J. Wuebbles, Harry E. Preble Professor of Atmospheric Science, University of Illinois (moderator)

9:30 AM Science in Action

U.S. Department of Energy National Labs Advancing Actionable Climate Projections

New advances in computing, including artificial intelligence, are revolutionizing the accuracy of climate models. In this conversation, researchers from U.S. Department of Energy national laboratories will outline the path and vision for developing models that meet two key needs: projecting climate impacts decades in the future and delivering highly accurate data for individual regions and cities. They will discuss how these high-resolution climate projections will provide actionable information that individual communities can use to build resilience.

Speakers

- Peter Caldwell, Research Scientist, Program for Climate Model Diagnosis and Intercomparison, Lawrence Livermore National Laboratory
- Rao Kotamarthi, Chief Scientist/Department Head, Atmospheric Science and Climate Research, Argonne National Laboratory (moderator)
- Lai-yung Ruby Leung, Battelle Fellow, Earth Science, Pacific Northwest National Laboratory

9:50 AM Break

10:05 AM Keynote

Climate Policy in the 117th Congress

U.S. Representative Sean Casten

10:35 AM Science in Action

Climate and Environmental Justice in Urban Communities

More than 80% of the U.S. population lives in urban areas, where the weather systems that affect climate locally are complex and poorly understood. This conversation will explore how the climate modeling community can incorporate the needs of all communities—especially those historically left out of climate discussions and decisions—and provide the data and models to create cities where all communities are equally resilient to climate change and benefit from investments in a clean energy society.

Speakers

- Georges Benjamin, Executive Director, American Public Health Association
- Luis Bettencourt, Director, Mansueto Institute for Urban Innovation, University of Chicago

11:00 AM Panel Discussion

Improving Resilience: Developing Strategies and Overcoming Barriers to Proactively Adapt to Climate Change Risks

Climate change affects the critical functions of communities nationwide—disrupting the provision of health care, education, and financial services; cutting people off from electricity, natural gas, phone, and internet; and shrinking viable real estate and transportation byways. This panel discussion focuses on how industries, governments, and other private and public organizations have increased their resilience in the face of climate change, what is needed to further improve resilience, and the kinds of data and tools being developed to proactively and effectively reduce disruptions.

Speakers

- David K. Brannegan, Division Director, Decision and Infrastructure Sciences, Argonne National Laboratory (moderator)
- Alice C. Hill, David M. Rubenstein Senior Fellow for Energy and the Environment, Council on Foreign Relations
- Adrienne Lotto, Vice President and Chief Risk and Resilience Officer, New York Power Authority
- Lucia Schmit, Recovery Project Manager, Office of Mayor Jenny A. Durkan, City of Seattle

11:50 AM Science in Action
Increasing Infrastructure Adaptation and Resilience to Climate Impacts
Industries grapple with the impacts of climate every day as they plan for future service delivery and growth. The telecom industry is no exception, and AT&T has used leading-edge climate models to better plan their response and growth given current climate projections. This case study details how AT&T uses regional-scale projections to anticipate and improve resilience to climate change and, in doing so, strengthens their infrastructure and operations decades into the future.

Speakers

- Gavin Anderson, Principal-System Engineer, AT&T
- Shannon Thomas Carroll, Director of Global Environmental Sustainability, AT&T
- Thomas A. Wall, Program Lead, Engineering & Applied Resilience, Argonne National Laboratory (moderator)

12:10 PM Break

12:30 PM Improving Resilience
Adaptation Across America: Local and Regional Perspectives on Climate Resilience
Regional and local officials often find themselves at the front lines of climate adaptation as they seek to meet the needs of communities facing increasing threats from climate change. In this session, three officials from across the United States will discuss the actions being taken within their regions in response to climate change, the knowledge basis used to drive these actions, and offer their perspective on the pathways needed to enhance climate resilience into the future.

Speakers

- Cameron Davis, Commissioner, Metropolitan Water Reclamation District of Greater Chicago; Vice President, GEI Consultants, Inc.
- Susanne DesRoches, Deputy Director, Infrastructure + Energy, NYC Offices of Sustainability and Resiliency
- Jennifer Jurado, Chief Resilience Officer, Deputy Department Director, Broward County Government

1:25 PM Keynote with Q&A
U.S. Secretary of Energy Jennifer Granholm

2:00 PM Event Concludes

APPENDIX B: KEYNOTE SPEAKERS

Jennifer Granholm
U.S. Secretary of Energy

Jennifer M. Granholm was sworn in as the 16th Secretary of Energy on February 25, 2021, becoming just the second woman to lead the U.S. Department of Energy (DOE).

Secretary Granholm will lead DOE in helping America achieve President Biden's goal of net-zero carbon emissions by 2050 by advancing cutting-edge clean energy technologies, creating millions of good-paying union clean energy jobs, and building an equitable clean energy future. Secretary Granholm will also oversee DOE's core missions of promoting American leadership in scientific discovery, maintaining the nuclear deterrent and reducing nuclear danger, and remediating the environmental harms caused by legacy defense programs.

Prior to her nomination as Secretary of Energy, Jennifer Granholm was the first woman elected Governor of Michigan, serving two terms from 2003 to 2011.

As Governor, Jennifer Granholm faced economic downturns caused by the Great Recession and meltdown in the automotive and manufacturing sectors. She successfully led efforts to diversify the state's economy, strengthen its auto industry, preserve the manufacturing sector, and add emerging sectors—such as clean energy—to Michigan's economic portfolio. Today, one-third of all North American electric vehicle battery production takes place in Michigan, the state is one of the top five states for clean energy patents, and 126,000 Michiganders were employed in the clean energy sector prior to COVID-19.

Secretary Granholm was also the first woman elected Attorney General of Michigan and served as the state's top law enforcement officer from 1998 to 2002.

After two terms as governor, Jennifer Granholm joined the faculty of the University of California, Berkeley as a Distinguished Professor of Practice in the Goldman School of Public Policy, focusing on the intersection of law, clean energy, manufacturing, policy, and industry. She also served as an advisor to the Clean Energy Program of the Pew Charitable Trusts.

Jennifer Granholm began her career in public service as a judicial clerk for Michigan's 6th Circuit Court of Appeals. She became a federal prosecutor in Detroit in 1990, and in 1994, she was appointed Wayne County Corporation Counsel.

Secretary Granholm, an immigrant from Canada, is an honors graduate of both the University of California, Berkeley and Harvard Law School. She and her husband, Daniel G. Mulhern, have three children.

Sean Casten
U.S. Representative

Sean Casten represents Illinois' 6th Congressional District, located in western suburbs of Chicago. Rep. Casten serves on the House Financial Services Committee, the Science, Space, and Technology Committee, the Select Committee on the Climate Crisis, and is a Co-Chair on the New Democrat Coalition Climate Change Task Force. As a scientist, clean energy entrepreneur, author, and now as a Member of Congress, Casten has dedicated his life to fighting climate change.

Rep. Casten earned a Bachelor of Arts in Molecular Biology and Biochemistry from Middlebury College in 1993, and then worked for two years as a scientist at the Tufts University School of Medicine in a laboratory investigating dietary impacts on colon and breast cancer. In 1998, he earned a Master of Engineering Management and a Master of Science in Biochemical Engineering from the Thayer School of Engineering at Dartmouth College.

Rep. Casten worked as a clean energy consultant and manager at Arthur D. Little from 1997 to 2000. He then served as the president and CEO of Turbosteam Corporation. In 2006, Casten co-founded Recycled Energy Development (RED), which focused on recycling wasted energy and converting energy facilities to cleaner, more economic uses. RED built, owned, and operated industrially-sited waste energy recovery plants throughout North America.

In Congress, Rep. Casten draws upon his previous private sector experience in order to craft market-based solutions that adequately address the threat of climate change in an effective, sustainable way.

While working diligently in Washington on behalf of Illinois' 6th Congressional District, Rep. Casten is also committed to keeping in close contact with his constituents, believing in the benefit of hearing the views and ideas of all of the people he represents. Sean and his wife Kara live in Downers Grove, Illinois, with their two daughters, Gwen and Audrey, who attend the local public schools.

Shalanda H. Baker
Deputy Director for Energy Justice
U.S. Department of Energy

Shalanda H. Baker is the Deputy Director for Energy Justice in the Office of Economic Impact and Diversity at the U.S. Department of Energy. Prior to her appointment, she was a Professor of Law, Public Policy and Urban Affairs at Northeastern University. She has spent over a decade conducting research on the equity dimensions of the global transition away from fossil fuel energy to cleaner energy resources. She is the author of over a dozen articles, book chapters, and essays on renewable energy law, energy justice, energy policy, and renewable energy development. In 2016, she received a Fulbright-Garcia-Robles research fellowship to study climate change, energy policy, and indigenous rights in Mexico. She is the Co-Founder and former Co-Director of the Initiative for Energy Justice (www.iejusa.org), an organization committed to providing technical law and policy support to communities on the frontlines of climate change.

Paul Kearns
Director, Argonne National Laboratory

Paul Kearns has served as director of the U.S. Department of Energy's Argonne National Laboratory since 2017. Kearns manages a growing multidisciplinary science and engineering research center with a $1.2 billion diversified research portfolio and more than 3,300 employees, 8,000 facility users, and 800 visiting researchers. Kearns served as Argonne chief operations officer from 2010 to 2017.

Kearns is a biologist and accomplished steward of diverse resources to achieve ambitious goals in energy, environment, and national security. For over 30 years, Kearns has managed complex research and development enterprises by prioritizing science and technology leadership, operations excellence, and world-class talent.

Juan de Pablo
Vice President for National Laboratories, Science, Strategy, Innovation and Global Initiatives and Liew Family Professor in Molecular Engineering, University of Chicago; Senior Scientist, Argonne National Laboratory

As the Vice President for National Laboratories, Science Strategy, Innovation, and Global Initiatives, Juan de Pablo provides leadership for the University's stewardship of two U.S. Department of Energy National Laboratories—Argonne and Fermilab—as institutions to advance science and technology in support of the nation's interest. de Pablo collaborates with other leaders in research and innovation to build programs and links between and among the national laboratories and the University, as well as the Marine Biological Laboratory. Working with President Robert J. Zimmer, he plays an essential role in the University's partnership with the Department of Energy.

A prominent materials scientist, de Pablo's research focuses on polymers, biological macromolecules, and liquid crystals, a diverse class of materials widely used in many fields of engineering. He is also a leader in developing molecular models and computer simulations of complex processes over wide ranges of length and time scales. He heads a research group that develops advanced algorithms to design and predict the structure and properties of complex fluids and solids at a molecular level.

As a key leader for the Pritzker School of Molecular Engineering, de Pablo's work has been essential to the School's development and remarkable growth. He joined the University in 2012 as a member of the first set of the School's faculty appointments. He came from the University of Wisconsin, Madison, where he served as the Howard Curler Distinguished Professor and Hilldale Professor of Chemical Engineering. He was awarded the 2018 Polymer Physics Prize by the American Physical Society.

de Pablo earned a bachelor's degree in chemical engineering from Universidad Nacional Autónoma de México, as well as a Ph.D. in chemical engineering from the University of California, Berkeley. He conducted postdoctoral research at the Swiss Federal Institute of Technology in Zurich, Switzerland. de Pablo was inducted into the National Academy of Engineering in 2016 for "design of macromolecular products and processes via scientific computation." He is a fellow of the American Academy of Arts and Sciences, the American Physical Society, and is a foreign correspondent member of the Mexican Academy of Sciences.

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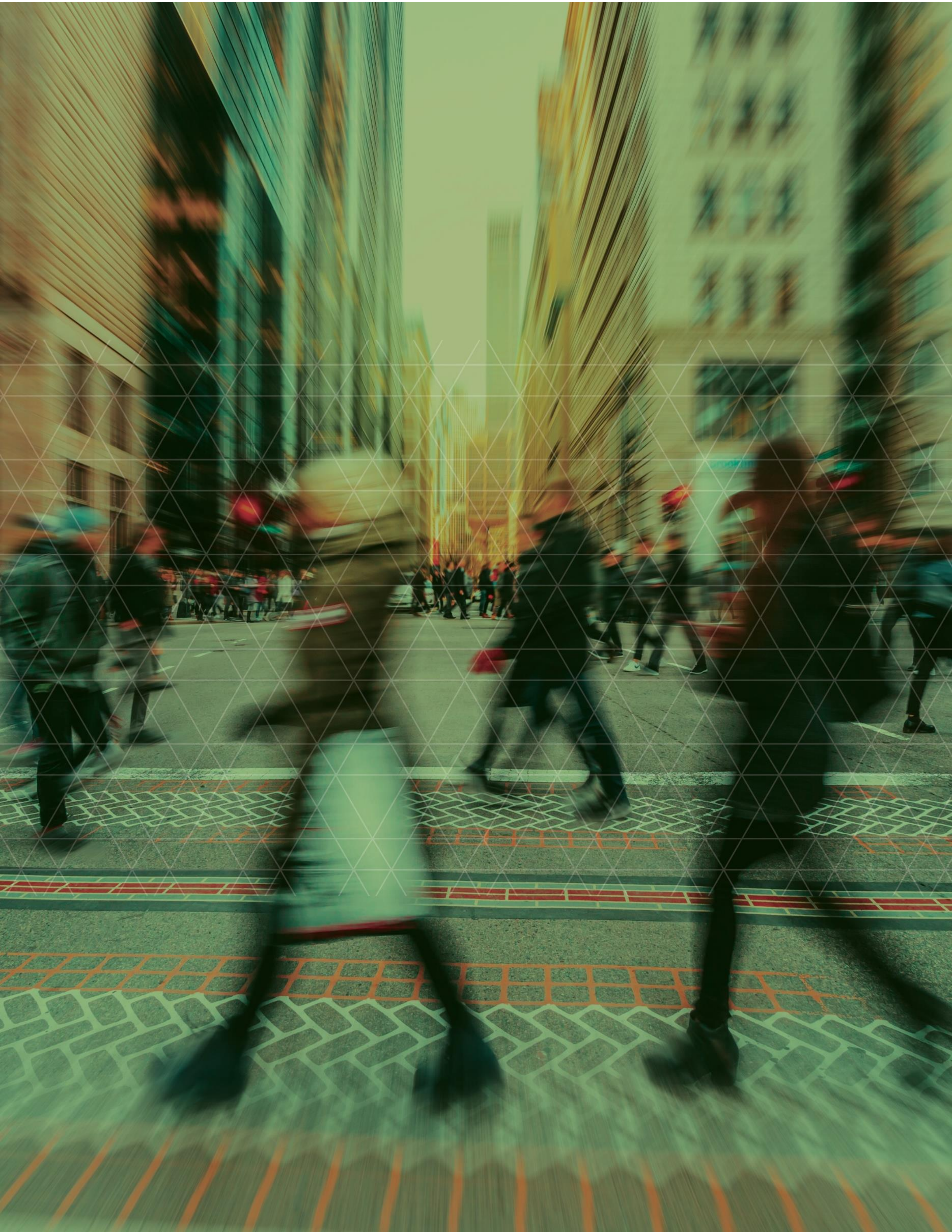

ABOUT ARGONNE NATIONAL LABORATORY

- U.S. Department of Energy research facility
- Operated by the University of Chicago
- Midwest's largest federally funded R&D facility
- Located in Lemont, IL, about 25 miles (40 km) southwest of Chicago, IL (USA)
- Conducts basic and applied research in dozens of fields
- Unique suite of leading-edge and rare scientific user facilities

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