2023 ANNUAL REPORT

MIT JOINT PROGRAM ON THE SCIENCE AND POLICY OF GLOBAL CHANGE

Director: Ronald G. Prinn

Massachusetts Institute of Technology

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INTRODUCTION

MISSION/VISION/IMPACT

Mission

Advancing a sustainable, prosperous world through actionable, scientific analysis of the complex interactions among co-evolving, interconnected global systems.

The pace and complexity of global environmental change is unprecedented. Nations, regions, cities and the public and private sectors are facing increasing pressures to confront critical challenges in future food, water, energy, climate and other areas. Our integrated team of natural and social scientists produces comprehensive global and regional change projections under different environmental, economic and policy scenarios. These projections enable decision-makers in the public and private sectors to better assess impacts, and the associated costs and benefits of potential courses of action.

Vision

We envision a world in which community, government and industry leaders have the insight they need to make environmentally and economically sound choices.

Toward that end, we provide a scientific foundation for strategic investment, policymaking and other decisions that advance sustainable development.

Impact: What We Do

The MIT Joint Program:

- Combines scientific research with risk and policy analyses to project the impacts of—and evaluate possible responses to—the many interwoven challenges of global socioeconomic, technological and environmental change.
- Communicates research findings through our website, publications, workshops and presentations around the world, as well as frequent interactions with decision-makers, media outlets, government and nongovernmental organizations, schools and communities.
- Cultivates and educates the next generation of interdisciplinary researchers with the skills to tackle ongoing and emerging complex global challenges.

FROM THE DIRECTOR

After a year of record-breaking heat and attendant climate impacts, as well as heightened geopolitical tensions, we remain committed to improving our understanding of critical global and regional change challenges, and to pursuing actionable, leading edge research on viable solutions.

For example, as global warming approaches 1.5°C—the aspirational upper limit set in the Paris Agreement—it is ushering in more intense and frequent heatwaves, floods, wildfires and other climate extremes much sooner than many expected. Current climate policies are far too weak to keep the planet from exceeding this threshold. Our *2023 Global Change Outlook* presents the Joint Program's latest projections for the future of the Earth's energy, food, water and climate systems under existing and aspirational global climate policies—and evaluates prospects for achieving the Paris Agreement's short- and long-term climate goals.

Other notable achievements in the past year include: (a) a new modeling tool that enables rapid design of effective, equitable policies that target climate and air pollution simultaneously, improving health outcomes; (b) enhancements to a computational platform that finds hotspots where compounding environmental and economic risks converge, thus empowering decision-makers to target interventions; (c) a study on how forests can become more effective "Natural Climate Solutions;" and (d) analyses on the contribution of the Inflation Reduction Act toward decarbonizing the U.S. economy and power sector. Through publications, briefings and conference presentations, our researchers have shared their study results and expertise with government and industry decision-makers in the U.S. and around the world.

In the coming year, we plan to upgrade our Integrated Global System Modeling (IGSM) framework to incorporate more detailed Earth-system modeling and enhance our capability to design policies that simultaneously address climate, air quality, equity, biodiversity and other sustainability goals. We will evaluate the climate implications of the new pledges made at the COP28 in Dubai. We will also assess risks to managed resources (e.g., water, land, crops, energy) in regions from Bangladesh to the Mississippi River Basin, and the likely impacts of extreme events on these resources.

We will continue to explore emissions pathways and policy strategies at regional and global levels aimed at achieving the Paris Agreement's long-term climate goals. Toward that end, we will analyze low-carbon technology pathways under different energy-transition scenarios, and assess the performance of technologies ranging from sustainable aviation fuels to direct air capture. We will also continue to evaluate climate-related physical and transition risks associated with different policy choices.

Finally, we will expand the Joint Program's data-visualization capabilities to include continued improvements to our STRESS platform and a new scenario discovery tool that identifies key factors that could lead to extreme outcomes.

We are grateful to our many Sponsors and Contributors for making this work possible. As we begin to pursue our 2024 plans, we look forward to continuing to share our research findings with our Program Sponsors through their exclusive communications channels, and with the public through our website.

Best regards,

Ronald Prinn • Director, MIT Joint Program on the Science and Policy of Global Change

PROGRESS IN 2023

RESEARCH HIGHLIGHTS

Research Focus Areas

The Program's core research focus areas center on projected global and regional changes and potential risks under different policy, economic and technology scenarios. Here we present highlights of the past year's progress for each research focus area.

Earth Systems: Understanding changes and risks to the interconnected land, ocean, atmosphere and biosphere system

At the core of our Earth-system modeling capability is the MIT Earth System Model (MESM), a flexible and computationally efficient tool designed to explore the myriad of plausible futures resulting from natural and human-forced changes. We also conduct numerical experimentation and analyses with more detailed representations, using a portfolio of machine-learning, data assimilation and explicit process-modeling methods. These studies provide "deeper-dive" impact assessments, improving our representation and understanding of the coupled mechanisms and responses among the Earth's atmosphere, land, freshwater, ocean and cryosphere systems.

Applying our Earth-system modeling tools in 2023, we constructed a suite of large-ensemble predictions that cover a range of climate policies and account for uncertainty in (a) the climate system response to anthropogenic emissions of greenhouse gases and (b) the geographical patterns of climate change. These data have been used to assess regional climate-related risks.

We continued to improve our methods to assess the ecosystems of the global oceans. We updated the global riverine and coastal wetland contribution of nutrients and carbon into the global oceans, and extracted climate-change-related trends in ocean ecology. We also advanced our understanding of the historical structure of forests and their response to extreme events, and developed novel metrics via machine learning to assess global biodiversity.

Finally, using machine learning, models and observations, we advanced scientific knowledge on the connections that link air chemistry (as well as pollutant and aerosol transports) to weather and climate, ocean sinks, human activities (e.g., contrails and supersonic aircraft) and extreme environments (e.g., wildfires). We also assessed the equity implications of air quality from U.S. decarbonization policies.

Managed Resources: Projecting changes and risks to managed agriculture, water, land and energy systems

Over the past year, we expanded our modeling capabilities to allow for more comprehensive and detailed assessments of managed land and water resources. In one study, we assessed the availability and quality of water resources in the Mississippi River Basin to disentangle the key environmental and socioeconomic drivers of change. In other work, we explored the potential changes in agricultural land-use patterns over the U.S. that result from various drivers and stressors of change. Our research tools also provided a scenario-discovery analysis of the policy instruments, technological assumptions and socioeconomic factors that will likely drive solar and wind transitions through the middle of the century.

Infrastructure & Investment: Projecting physical and transition risk, and adaptation and resilience to climate change and associated extreme events

We worked to combine our recent advances in machine-learning and empirically-based downscaling methods with more explicit and detailed models of local and urban infrastructure to assess flood risks. This allowed for enhanced predictions of flood risk using the MIT Campus as well as Cleveland as case studies. In other work, we provided guidance toward reliable and equitable solutions for adapting water resource systems under climate change. Our work also contributed to more comprehensive assessments and guidance for strategies that promote climate-resilient investment.

Energy Transition: Projecting the future energy mix nationally and globally, and prospects for different sectors and technologies

Our research helped enable decision-makers to make sound, forward-looking choices from an expansive menu of technology and policy options aimed at lowering greenhouse gas emissions. We continued to develop and use energy transition scenarios and assess their impacts on economies, emissions and the environment, while deepening our work on representing socio-economic uncertainty in human-system models. We also investigated some critical challenges for low-carbon technology deployment, including sustainable aviation fuels, iron and steel, direct air capture and the use of hydrogen for decarbonizing heavy industry. Finally, recognizing the importance of the U.S. Inflation Reduction Act for scaling up the energy transition, we evaluated its energy and emissions impacts.

Policy Scenarios: Projecting global and regional environmental and economic change under different policies aimed at climate and air pollution mitigation and economic development

We deepened our focus on the design of realistic, effective policies aimed at simultaneously reducing greenhouse gas emissions and air pollution. We investigated the effects of border carbon adjustments, health effects of a global carbon price, air quality-related equity implications of U.S. decarbonization policy, impacts of forestry land decisions in an emissions trading scheme, and use of natural climate solutions to ensure synergy with sustainable development. We continued to advance our representation of variable renewable energy deployment in low-emissions scenarios. Our policy scenario explorations also included modeling the impacts of reaching global net-zero emission goals by 2050. Finally, we updated our Economic Projection and Policy Analysis (EPPA) model and explored alternative scenarios in our 2023 Global Change Outlook.

Regional Analysis: Projecting sub-national, national and multi-national environmental and economic change under different policy scenarios

We continued to explore how local development plans can be affected by the performance of regional and global markets. In particular, we studied the changing nature of human-forced hydroclimatic risks across Africa, an emissions trading scheme in New Zealand, rising HFC emissions from eastern Asia, environmental impacts of the U.S. Inflation Reduction Act, and economic implications of border carbon adjustment mechanisms on the Canadian economy. Our economic analysis of hydrogen used to decarbonize heavy industry included impacts on China, India and the European Union. Our analysis of direct attribution of fires to human activities in the contiguous U.S. indicates a large mitigation potential for future management choices. We also explored how nuclear power phase-outs in the U.S. could affect air pollution, climate and health.

Multi-Sector Dynamics: Exploring potential tipping points and transition states of Earth and human systems at regional to sub-regional scales

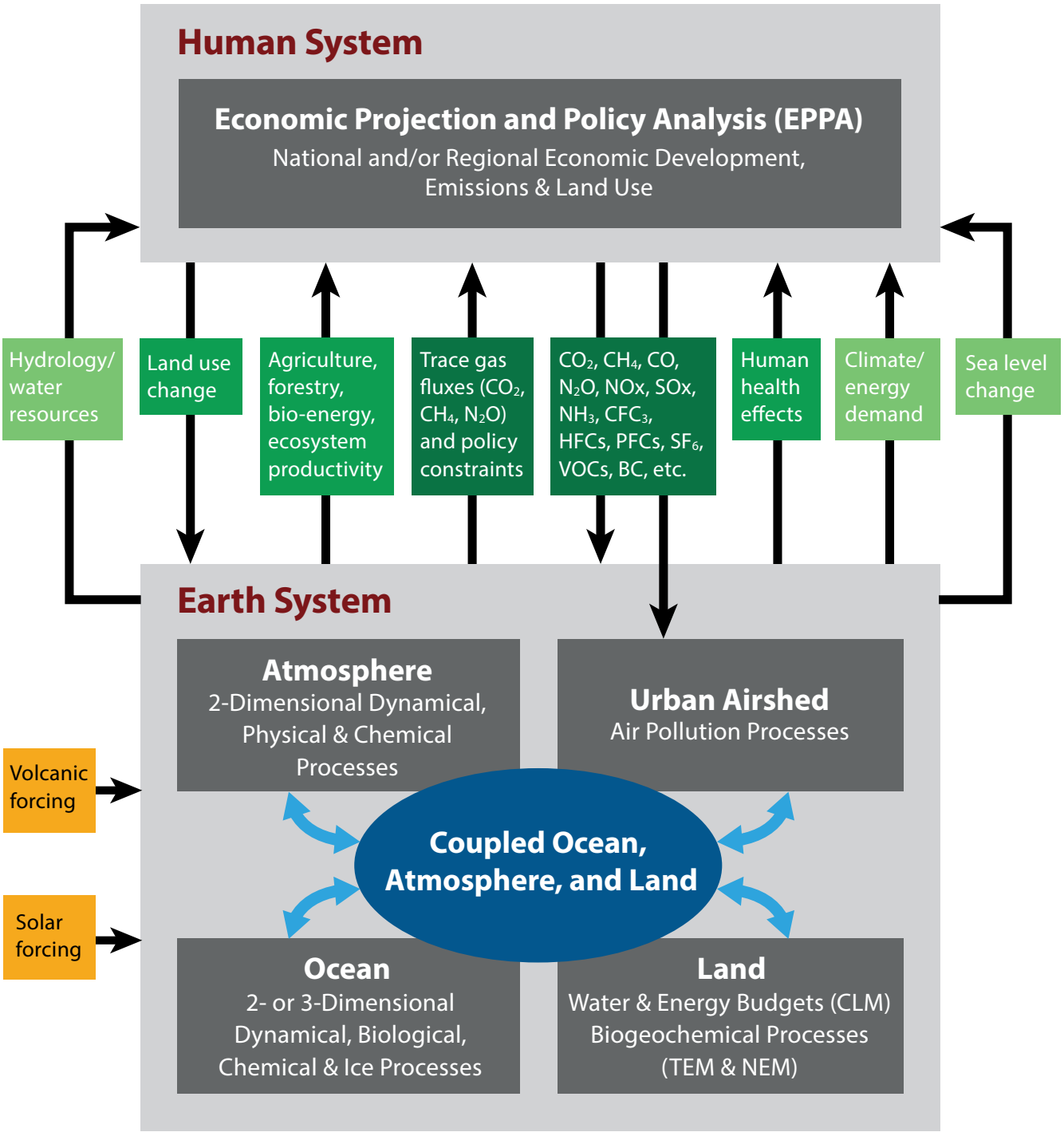
Given the multi-disciplinary underpinnings of multi-sector dynamics (MSD), we continue to actively collaborate with the scientific community. In so doing, we have worked to improve numerical methods that can represent and predict transitions and changes across human-Earth systems as well as identify pathways for nature-based solutions and sustainable development. Our MSD integrated prediction framework has also been enhanced with an efficient model component that can assess the impact and benefits of climate and air quality interactions that result from various environmental policies. Finally, we continued to enhance our System for the Triage of Risks from Environmental and Socioeconomic Stressors (STRESS) platform to provide additional variables and combinatory metrics as well as a global visualization map.

Modeling System

Our state-of-the-art models and analytical methods project global and regional changes and potential risks under different policy scenarios. Our modeling system consists of the MIT Earth System Model (MESM), the MIT Economic Projection and Policy Analysis (EPPA) model, the MIT Integrated Global System Modeling (IGSM) framework, and methods used to assess uncertainty and risk. Highlights of the past year's progress include:

- Documenting and updating the System for the Triage of Risks from Environmental and Socioeconomic Stressors (STRESS) platform
- Documenting a large-ensemble global dataset to support our climate-related impact assessments
- Creating and integrating an efficient model for climate-air chemistry interactions
- Documenting the USREP-ReEDS model used in the US EPA analysis of environmental impacts of the Inflation Reduction Act.

Integrated Global System Modeling (IGSM) Framework



Exchanges represented in standard runs of the system

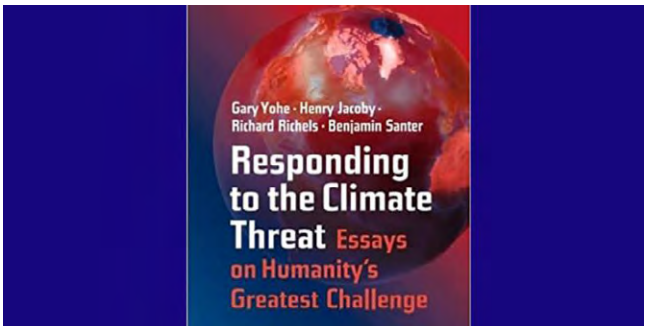
Exchanges utilized in targeted studies

Implementation of feedbacks is under development

PUBLICATION HIGHLIGHTS

Accelerated climate action needed to sharply reduce current risks to life and life-support systems

2023 Global Change Outlook quantifies benefits of policies that cap global warming at 1.5°C



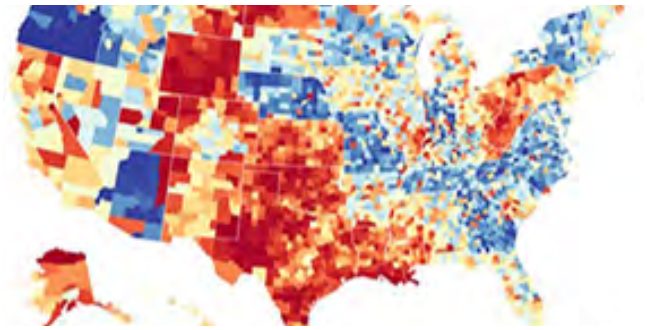
Responding to the Climate Threat: Essays on Humanity's Greatest Challenge

A new book co-authored by MIT Joint Program Founding Co-Director Emeritus Henry Jacoby

PHOTO SOURCE: WORLD BANK / FLICKR

Improving health outcomes by targeting climate and air pollution simultaneously

New modeling tool enables rapid design of effective and equitable policy combinations



Finding 'hotspots' where compounding environmental and economic risks converge

Computational tool empowers decision-makers to target interventions

PHOTO SOURCE: NASA / JOSHUA STEVENS

Study: The ocean's color is changing as a consequence of climate change

The color changes reflect significant shifts in essential marine ecosystems (MIT News) (Coverage: Washington Post, The Guardian, Boston Globe, CNN, CBS, Bloomberg, National Geographic, U.S. News & World Report, Forbes, Scientific American, New Scientist, Popular Science, Smithsonian, Axios, The Daily Beast)

Study: Shutting down nuclear power could increase air pollution

If reactors are retired, polluting energy sources that fill the gap could cause more than 5,000 premature deaths, researchers estimate (MIT News)

PHOTO SOURCE: CENUSA BIOENERGY / FLICKR

Net-zero emissions by 2050: Is the world willing to pay more to lock in its long-term climate goal?

Study finds tradeoffs between policy costs and ensuring that global warming does not exceed 1.5°C

PHOTO SOURCE: ALAN STARK / FLICKR

Improving U.S. air quality, equitably

Climate policy alone cannot meaningfully reduce racial/economic disparities in air pollution exposure

Cutting carbon, restoring ecosystems, creating jobs

How forests can become more effective 'Natural Climate Solutions'

PHOTO SOURCE: AGU

AGU Fall Meeting to encourage the pursuit of Open Science

MIT Joint Program presentations highlight multiple sustainability challenges and solutions

EPA releases report: Electricity Sector Emissions Impacts of the Inflation Reduction Act

Report relies substantially on MIT Joint Program's U.S. Regional Energy Policy (USREP) model projections (U.S. EPA)

Links to 2023 Publications

- All
- Journal Articles
- Joint Program Reports
- Other Publications (Includes AGU presentations)

By Focus Area:

- Earth Systems
- Managed Resources
- Infrastructure & Investment
- Energy Transition
- Policy Scenarios
- Regional Analysis
- Multi-Sector Dynamics

MEDIA COVERAGE

News Stories

2023 Economic Report of the President released

Report cites paper co-authored by MIT Joint Program researchers on climate effects on U.S. infrastructure (White House Council of Economic Advisors)

The underbelly of electric vehicles

What goes into making EVs, where it comes from and at what human cost (Washington Post)

America needs clean electricity. These states show how to do it.

MIT Joint Program Principal Research Scientist Jennifer Morris comments on the viability of the nuclear power option (Washington Post)

Are electric cars really better for the environment?

Overall, they're much less harmful than gasoline cars, says MIT Joint Program Deputy Director Sergey Paltsev (Washington Post)

This study upends how we think about the ozone layer and our health

The ozone layer's effect on our lives may be more complicated than it seems (Washington Post)

Could Air Someday Power Your Flight? Airlines Are Betting on It.

New technologies, including one fuel extracted from the atmosphere itself, could make flying more sustainable. But the challenges are many and the timeline is uncertain. (New York Times)

EPA updates emissions standards for heavy-duty vehicles for the first time in 20 years

Heavy-duty vehicles contribute about 23 percent of greenhouse gas emissions from the transportation sector (Popular Science)

MIT climate scientist urges action after hottest days on record

MIT Joint Program Deputy Director Sergey Paltsev responds to new report showing global average temperature reaching 17.18°C (62.9°F) (WCVB (ABC Affiliate))

News outlets that have covered Joint Program activities include:

ABC-Boston	MIT Climate Portal
Axios	Monga Bay
Bloomberg	National Geographic
Boston Globe	Nature Sustainability
CBS	New Scientist
CNN	The New Times
Daily Beast	New York Times
DW	PNAS
Economic Times	Popular Science
Forbes	Scientific American
The Guardian	Smithsonian
The Hill	U.S. News & World Report
Live Science	Washington Post
Maine Monitor	White House

Will the drive for EVs destroy Earth's last untouched ecosystem?

In the hunt for minerals needed in electric car batteries, some companies are turning to the deep sea. But mining this ecosystem could threaten its very existence. (Live Science)

Hooked on heating oil: Maine's reliance on a dirty, expensive fuel

MIT Joint Program's STRESS platform shows that Maine counties have the highest risk in the region of having both high energy expenditures and high poverty rates (The Maine Monitor)

Climate: Is 1.5 degrees Celsius still achievable?

Held up as the temperature limit that should not be crossed, 1.5 degrees Celsius is more than just a number. So what's behind it, and what happens if it is exceeded? (DW)

Dubai and India accelerate sustainable mobility ahead of COP28

Ahead of COP28, the UAE's EV market is booming, bolstered by private investments, government initiatives, and partnerships with countries such as India (The Economic Times)

Internal combustion vs. EVs: Learning from the past to boost sustainability

MIT Joint Program Deputy Director Sergey Paltsev identifies opportunities to make EVs more sustainable (Mongabay)

PODCAST: Don't throw away your refrigerator

MIT Joint Program Director Ronald Prinn joins TILclimate to discuss the past, present and future of how refrigerants affect our planet. (MIT Climate Portal)

Why have electric vehicles won out over hydrogen cars (so far)?

Today's battery electric vehicles are cheaper than hydrogen-powered ones, and they also need less new infrastructure (MIT Climate Portal)

ASK MIT CLIMATE: Will climate change drive humans extinct or destroy civilization?

Almost certainly not—but unless we act quickly to stop warming the planet, there will be very severe consequences for many, many people (MIT Climate Portal)

ASK MIT CLIMATE: How long will it take temperatures to stop rising, or return to 'normal,' if we stop emitting greenhouse gases?

Temperatures will likely stop rising in a few years or decades—but it could take centuries for them to fall to the levels humans enjoyed before we started burning fossil fuels (MIT Climate Portal)

Rwanda's president appoints atmospheric scientist Gasore as new Infrastructure Minister

Former MIT EAPS PhD student Jimmy Gasore developed Africa's only AGAGE atmospheric gases monitoring station (The New Times)

Commentaries

Tipping into the danger zone—we need to learn more about climate tipping points

A call for a concerted scientific effort to understand the risks posed by exceeding them (The Hill)

Don't let the Heritage Foundation's denialism 'Mandate' drive our climate agenda

Co-authors say map presented in the Mandate is of 'a road to ruin' (The Hill)

Young Republicans want action on climate change — so why is the party ignoring them?

Studies show an emerging divide between younger and older Republicans that could help shift the party's stance on climate policy (The Hill)

Progress in modeling dynamic systems for sustainable development

MIT Joint Program faculty affiliate Noelle Selin and co-authors highlight recent advances in modeling Earth/human systems dynamics to inform sustainable development (PNAS)

Health effects of a global carbon price

A study shows that while air quality gains from carbon policies are widespread, some regions could see pollution increases (Nature Sustainability)

PROJECT HIGHLIGHTS

New Projects

Hydrogen: Assessing vulnerabilities in global terrestrial & atmospheric sinks & leakage risks to unintended climate consequences

Leader: C. Adam Schlosser
Sponsor: MITEI Future Energy Systems Center (FESC)
Duration: 2 years

Options for decarbonizing aviation in Latin America in a sustainable way: an assessment of carbon policies, carbon prices and fuel consumption in aviation up to 2050

Leader: Sergey Paltsev
Sponsor: Airbus Americas Inc. and LATAM Airlines Group S.A.
Duration: 1 year

Analysis of National Hydrogen Supply Chain Scenarios

Leader: Sergey Paltsev
Sponsor: National Petroleum Council via MIT Energy Initiative
Duration: 1 year

Economy-Wide Impacts of Environmental Changes and Responses

Leader: Jennifer Morris
Sponsor: Millennium Challenge Corporation (A cooperative agreement with MCC in collaboration with Auckland University of Technology and Industrial Economics, Inc.)
Duration: 3 years

Taiwan's Innovative Green Economy Roadmap (TIGER)

Leaders: Robert Armstrong and Sergey Paltsev
Sponsor: Consortium of Taiwan-based companies (via MITEI)
Duration: 2 years

Ongoing Projects

Sectoral Interactions, Compounding Influences and Stressors, and Complex Systems: Understanding Tipping Points and Non-Linear Dynamics:

Presented several papers at the 2023 American Geophysical Union Annual Meeting on water availability and quality, land-use change, and scenario discovery. Published paper in *Frontiers of Climate* and *Scientific Data*.

MIT Climate Grand Challenges Flagship Project: Bringing computation to the climate challenge

Presented paper at the 2023 AGU Annual Meeting

Advanced Global Atmospheric Gases Experiment (AGAGE) collaborative project: MIT component

Presented paper on long-term observations on non-CO_2 greenhouse gas concentrations at the 2023 AGU Annual Meeting

The impact of climate change on global health

Developed a machine-learning methodology to create an aggregate metric on the state of global biodiversity

Identifying Strategic Pathways Toward Sustainability: An integrated approach to address climate and human health

Published paper on an efficient emulator to assess air-quality/health impacts in peer-reviewed journal

MIT Climate Grand Challenges Flagship Project: Reinventing climate resilience and climate change adaptation with the Climate Resilience Early-Warning System Network (CREWSNet):

Published paper in *Scientific Data* on our supporting data for climate-driven impacts over Bangladesh

Negative Emissions Technologies and Hydrogen

Completed thesis on exploring the role of hydrogen in decarbonizing heavy industry

The role and value of carbon dioxide removal pathways in delivering the Paris Agreement's 1.5-2ºC objectives

Paper presented at the 2023 AGU Annual Meeting

U.S. Regional Energy Model

Published papers in *Science* and *Environmental Research Letters*

See more ongoing projects

OUTREACH HIGHLIGHTS

Global Change Forum

The annual, invitation-only MIT Global Change Forum brings together a targeted community involved in global change research and policymaking, and serves as a prominent vehicle to convey results to our sponsor members. A group of approximately 100 representatives from industry, government, international bodies, academia and research organizations meet for discussions on the evolving understanding of and issues regarding global change science and policy. The Forum promotes interaction and frank interchange among disparate stakeholders, and provides an unofficial, neutral, "off-the-record" setting for independent assessment of studies and policy proposals. No official transcripts are made of the sessions, and presentation slides are not made public without the consent of the speakers.

UPCOMING:
XLVI (46th) MIT Global Change Forum
March 28–29, 2024

Theme: The heat is on: Accelerating climate action at a time of record-breaking temperatures

Sessions:

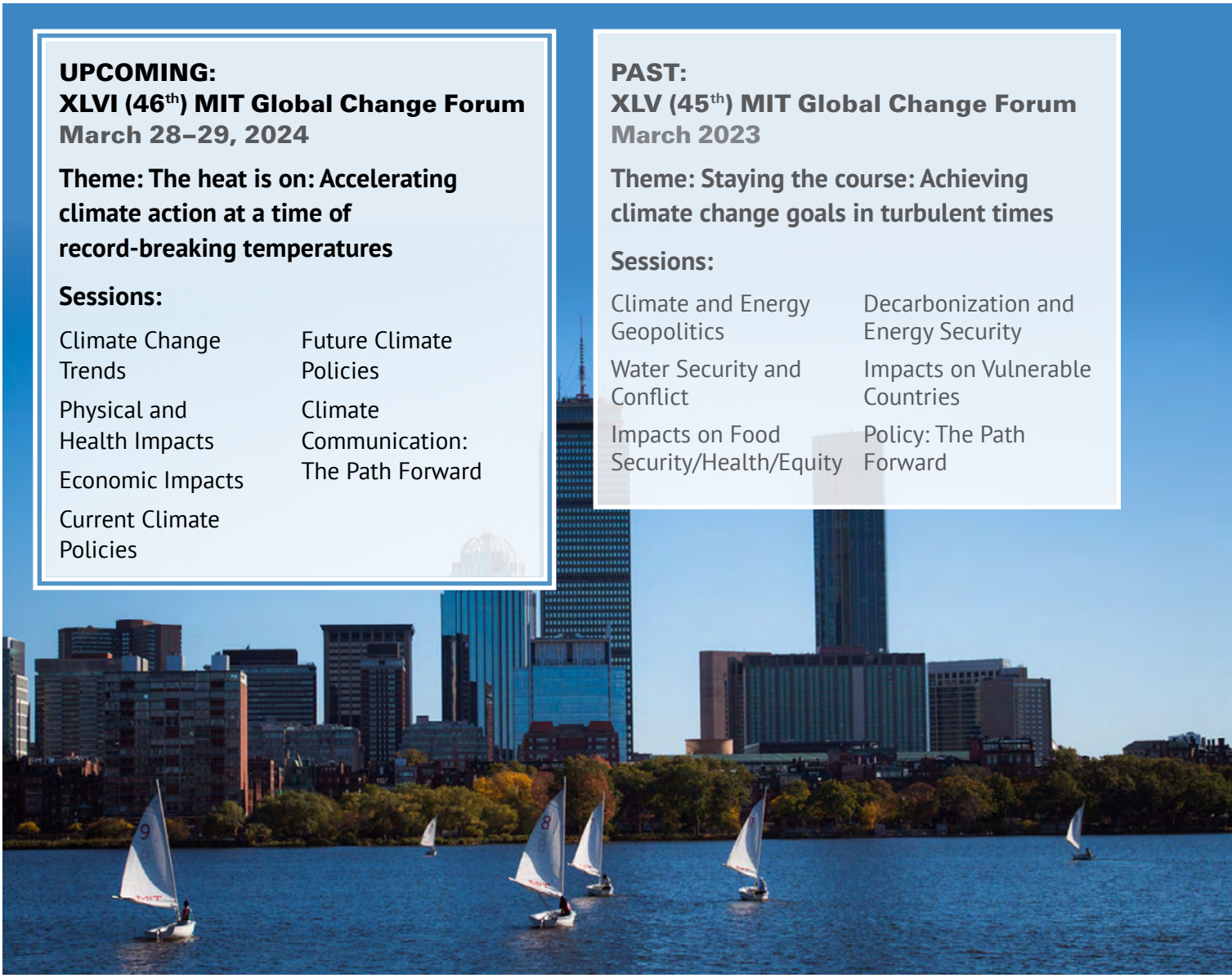
- Climate Change Trends
- Physical and Health Impacts
- Economic Impacts
- Current Climate Policies
- Future Climate Policies
- Climate Communication: The Path Forward

PAST:
XLV (45th) MIT Global Change Forum
March 2023

Theme: Staying the course: Achieving climate change goals in turbulent times

Sessions:

- Climate and Energy Geopolitics
- Water Security and Conflict
- Impacts on Food Security/Health/Equity
- Decarbonization and Energy Security
- Impacts on Vulnerable Countries
- Policy: The Path Forward



Workshops

The Joint Program's online/in person **Workshop Series** on leading-edge, actionable global change research is of particular interest to our sponsors and stakeholders, and exists to facilitate dialogue on issues spanning our research domain.

2023 Global Change Outlook (Winter 2024). This workshop will highlight the 2023 Outlook's key findings and their relevance for decision-making. Based on a rigorous, integrated analysis of population and economic growth, technological change, Paris Agreement emissions-reduction pledges, geopolitical tensions, and other factors, the report presents our latest projections for the future of the Earth's energy, food, water and climate systems, as well as prospects for achieving the Paris Agreement's short- and long-term climate goals.

Tipping Points (Spring 2024). This workshop will focus on the latest research on tipping points and the risks they pose for interconnected natural and human systems. Tipping points can occur when these systems can no longer sustain multiple, co-evolving stresses, such as extreme events, population growth, land degradation, drinkable water shortages, air pollution, aging infrastructure and increased human demands. The ability to identify key precursory indicators of such tipping points can provide decision-makers with critical information that can be applied to mitigate risks and boost resilience in infrastructure and managed resources. This workshop will bring together a range of experts and stakeholders to discuss definitions of tipping points and approaches for identifying, modeling and estimating them in the context of multi-sector dynamics.

Individualized Workshops and Webinars

2023 Global Change Outlook (Wellington Management, Fidelity, Woodside Energy)

Projecting Future Energy Systems (Equinor)

Climate Scenario Analysis with the MIT Economic Projection and Policy Analysis (EPPA) model (U.S. Financial Stability Oversight Council)

Energy, Climate and Bridge Fuels (MIT Environmental Solutions Initiative (ESI) Journalism Fellow Program)

Earth-human systems research and data-visualization tools (MIT ESI Journalism Fellow Program)

Energy Economics and Climate Policy for Financial Institutions (MFS Investment Management)

Carbon Capture and Storage in Global Emissions Mitigation (TotalEnergies)

MIT-IMPACTS: Quantifying effects on national economic growth (Millennium Challenge Corporation (MCC))

Presentations and Briefings

Our researchers engage in numerous visits, meetings and talks at U.S. federal agencies, research centers, and U.S. and international conferences—and discussions with foreign dignitaries.

Selected Policy Impact Activities for 2023

Conference Presentations

Participation in MIT-led side event (with Penn State and AGU) at COP28 in Dubai (Session Title: Knowledge to Action: Co-developing Local Solutions to the Climate Crisis)

MIT Global Change Forum: Annual Forums convene approximately 100 invited representatives of industry, government, non-governmental organizations, national and international policymaking bodies, and research groups

Publications

Contribution to the U.S. EPA analysis of electric sector emission impacts of the Inflation Reduction Act

Contribution to the analysis of emission and energy impacts of the U.S. Inflation Reduction Act

2023 Global Change Outlook: Charting the Earth's Future Energy, Managed Resources, Climate, and Policy Prospects

Briefings

Briefing on climate impacts on economy for the staff director of the Senate Budget Committee

Brazil Civil House: Briefing on the impacts of Brazil's proposed legislation on sustainable aviation fuels

Briefing to U.S. Financial Stability Oversight Council on climate scenario analysis with the MIT Economic Projection and Policy Analysis (EPPA) model

Bank of Canada: Briefing on the effects of border carbon adjustments on the Canadian economy

U.S. Environmental Protection Agency: Briefing on economic, distributional and health consequences of U.S. greenhouse gas emissions objectives that could be achieved using Section 115 of the U.S. Clean Air Act

Norway's Ministry of Energy: Briefing to the State Secretary on policy impacts for hydrogen deployment support in Europe

Environmental Defense Fund: Briefing on the role of oil and gas in 1.5 and 2°C scenarios

Events:

Advanced Global Atmospheric Gases Experiment (AGAGE) 45th Anniversary
Agricultural and Applied Economics Association (AAEA) Annual Meeting
American Geophysical Union (AGU) Annual Meeting
Association for the Science of Limnology and Oceanography Meeting
Boston College - Center for Earth System Science & Global Sustainability Workshop
CERAWeek
Cornell University - Energy & Water Resources Systems Seminar
GCAM Community Modeling Meeting
Global Trade Analysis Project (GTAP) 26th Annual Conference on Global Economic Analysis
Integrated Assessment Modeling Consortium (IAMC) Annual Meeting
Integrated Hydro-Terrestrial Modeling (IHTM) Workshop
MIT CEEPR European Energy Policy Conference
MIT CEEPR Spring Workshop
MIT Climate & Sustainability Consortium
MIT/FACT Alliance Workshop
MIT Global Change Forum XLV
MIT Zero Impact Aviation Alliance Fall Workshop
MITEI Congressional Senior Staff Seminar
NASA Joint Science Workshop
Neural Information Processing Systems (NeurIPS) Workshop
Sao Paolo Regional Discussion Forum on Aviation Energy Transition
Senior Congressional Staff Seminar
Snowmass Climate Impacts Workshop
UC Davis - Multi-Sector Dynamics Workshop
U.N. Climate Change Conference (COP28)
Workshop on Human Well-Being

Committees, Councils, and Working Groups:

American Geophysical Union (AGU)
Brookings Climate Scoring Taskforce
Denmark Technical University Marine Life Institute (Advisor)
Earth's Future: Special section on INFORMS
Integrated Assessment Modeling Consortium (IAMC)
Int'l Association for Energy Economics (IAEE)
Int'l Civil Aviation Organization - Aviation Environmental Protection Committee
Massachusetts Climate-Hydro Scientific Advisory Panel
MIT Climate & Sustainability Consortium
MITei External Advisory Board
Multi-Sector Dynamics (MSD) Community of Practice
Northeast Regional Stakeholder Workshop: The Climate-Food-Energy-Water Nexus
Ocean Carbon & Biogeochemistry (OCB) working group: Mixotrophs & Mixotrophy
SCOR COBS working group
Society for Decision Making Under Deep Uncertainty (DMDU)
TARA Oceans Consortium Executive Board
US Farm and Ranchers Association (USFRA) Science Advisory Board
Vegetation Impact Assessment Group
U.S. Association for Energy Economics (USAEE)
U.S. DOE - MSD PI Working Group
DOE BER Working Group and Subcommittee on Unified Data

Peer review provided for:

Applied Energy
Artificial Intelligence for Earth Systems
Atmospheric Chemistry & Physics
Business Strategy & the Environment
Climate Monitoring
Climate Policy
Economic Modelling
Energies
Energy & Climate Change
Energy Economics
Energy Policy
Environment & Development Economics
Environmental Modeling and Assessment
Environmental Modelling & Software
Frontiers in Climate
Frontiers in Earth Science
GTAP 26th Annual Conference
Int'l Journal of Green Energy
Int'l Journal of Greenhouse Gas Control
Journal of Applied Meteorology and Climatology
Journal of Cleaner Production
Journal of Economic Surveys
Journal of Geophysical Research: Atmospheres
Journal of Global Economic Analysis
Lancet Planetary Health
MISTI GSF Scientific Review Committee
Nature Climate Change
Nature Communication
NASA Postdoctoral Program (NPP)
NPJ Climate and Atmospheric Science
NSF Growing Convergence Research
Renewable Energy
Resources, Conservation & Recycling
Science
Swiss National Science Foundation
U.K. Research & Innovation
U.S. DOE Panel Review
U.S. DOE Early Career Research Program

Other Presentations:

Airbus-LATAM Airlines
Bank of Canada
BRAC
Brazil National Agency of Civil Aviation
Cargill
Cornell University
Dalhousie University
Freddie Mac Seminar Series
Global Council for Science and Environment
Government of Brazil
Government of Chile
Government of Colombia
Harvard University
New England Water Works Association
University of Minnesota
U.S. Congressional Budget Office
U.S. Financial Stability Oversight Council
Weimer School of Advanced Studies in Real Estate and Land Economics

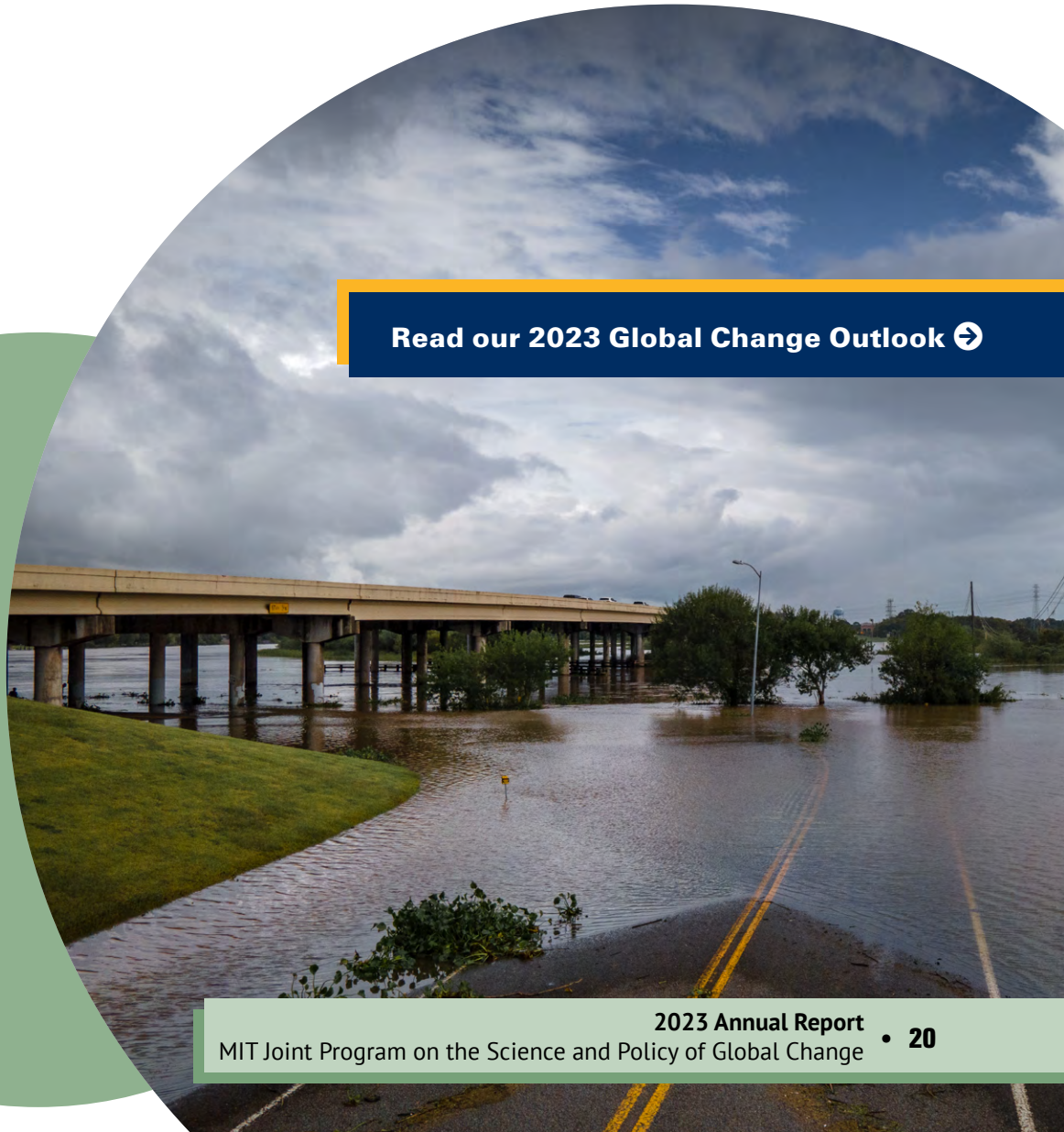
Online Outreach

We continue to maintain multiple online deliverables and channels for publicizing our research:

- Global Snapshot: Our monthly e-newsletter containing news releases and media coverage
- Global Changes: Our biannual digest featuring insights from our leadership on global changes and their implications; clickable summaries of news releases and media coverage of our research; and new projects, publications and professional milestones
- Annual Report: Our annual report to Program supporters (abridged for the general public) highlighting progress from the past year and plans for the coming year
- Global Change Outlook: Our biannual publication charting the Earth's energy, managed resources, climate and policy prospects

To stay up to date on MIT Joint Program activities, visit our website, subscribe to our email list and follow our social media platforms:

- Facebook
- Twitter (X)
- LinkedIn
- YouTube



ADMINISTRATIVE HIGHLIGHTS

Our team is composed of specialists working together from a wide range of disciplines. Founded in 1991 jointly with the MIT Center for Energy and Environmental Policy Research (CEEPR), the Joint Program is a partnership of the MIT Center for Global Change Science (CGCS) and the MIT Energy Initiative (MITEI), with participants from all five MIT Schools.

Information Systems

All computational resources in the svante cluster are housed in the Massachusetts Green High Performance Computing Center (MGHPCC) in Holyoke, Mass., a data center dedicated to research computing. The MGHPCC is operated by MIT in collaboration with Boston University, Harvard University, Northeastern University and the University of Massachusetts. The MIT Joint Program provides some hardware and maintenance support for the computational cluster.

Key updates in 2023 include:

- Major upgrade of the svante cluster that we use extensively in our research, raising the compute-capacity from 100 to 136 nodes.
- The newly purchased compute nodes communicate using an upgraded HDR200 network.
- We currently maintain 5,000+ cores (up from 3,300 in 2022).
- We have installed a GPU-based compute node for advanced machine-learning computations.
- We now maintain 13 high-capacity file-server units (up from 12 in 2022).
- Data-storage capacity upgraded to 4.6+ petabytes (PB) (a 600 terabyte increase from 2022).

Membership

The Joint Program is supported by an international consortium of government, industry and foundation sponsors, and individual donors.

During 2023, the Joint Program was supported by 39 sponsors and contributors, including several agencies of the U.S. federal government. Many sponsors provide general funding for the Joint Program, without delineating specific work tasks—though some prefer to give targeted support for specific components of our work.

Full list of all 2023 Sponsors and Contributors.

Personnel

Please visit our Personnel webpage to see biographical information, research interests, publications, and media mentions for all program staff and affiliates.

Personnel changes

Horacio Caperan • Executive director for external affairs • transferred to MIT Sloan Latin America office

Solene Chiuquier • Postdoc • Climate change mitigation and CO_2 removal pathways

Kenny Cox • Research Associate (former student) • uncertainty characterization

Sebastian Eastham • Principal research scientist • left for faculty position at Imperial College London

Aryeh Feinberg • Postdoc • completed two-year study of atmospheric mercury uptake by vegetation

David Kicklighter • Research Associate at the Marine Biological Laboratory • retired after 31 years of collaborating with the Joint Program on modeling land ecosystems

Sami Shokrana • Postdoc • Impacts of climate change on urban flooding in coastal settings

Popat Salunke • Postdoc • Numerical experimentation with the MIT Earth System Model

Visitors to the program

Gustav Fredriksson • Doctoral student in climate economics, ETH Zurich, Switzerland

Shih-Mo Lin • Professor of international business, Chung-Yuan Christian University, Taiwan

Sonia Yeh • Professor in transport and energy systems, Chalmers University of Technology, Sweden

Niven Winchester • Professor of economics, Auckland University of Technology, New Zealand

Completed Student Work

Emission mitigation in the global steel industry: representing CCS and hydrogen options in integrated assessment modeling. Kali Benavides, MS [Sergey Paltsev]

The impact of energy policy on climate and air quality. Elisabeth Freese, PhD [Noelle Selin]

Continuing Student Work

Efficient and rigorous climate and air pollution predictions. Yuan Chen, PhD research [Noelle Selin and Sebastian Eastham]

Developing better tools to assess the human health impact from air pollution and climate change. Emmie Le Roy, PhD research [Noelle Selin]

The future of global biodiversity: Developing novel, aggregate metrics that define target-based, integrated scenarios. Kevin Lin Yang, MS research [Adam Schlosser]

The future of food. Christopher Maynard, MS research [Ken Strzepek]

Improving numerical methods for climate simulations and policy relevance. Chris Womack, PhD research [Noelle Selin and Sebastian Eastham]

PLANS FOR 2024

FOCUS AREAS

Our plans for each of the Program's core research focus areas.

Earth Systems: Understanding changes and risks to the interconnected land, ocean, atmosphere and biosphere system

We have successfully completed our initial testing and evaluation of a more spatially detailed Earth-system model—the Community Earth System Model (CESM) within the IGSM framework. In the coming year, we will execute CESM with our 2023 Outlook scenarios to document, evaluate and demonstrate the enhanced features CESM is able to provide as part of the IGSM's scenario development and impact assessments. This work will also contribute to a campus-wide collaboration across MIT to develop a "digital twin" of the Earth system using machine learning, advanced modeling and AI methods.

In other work, we will continue to expand the capabilities of our model components that provide climate and air-chemistry/quality assessments. These include the Tool for Air Pollution Scenarios (TAPS) model component as well as an efficient model for air-quality impacts. Embedding these components into the IGSM framework will allow for the development of combined climate and human-health targets. In a complementary effort, we will develop metrics that quantify the state and intactness of global biodiversity, and explore how these metrics can be used in the design of biodiversity-based targets. Ultimately, we can integrate biodiversity, climate and human-health targets to develop pathways that provide more comprehensive global sustainability solutions.

Managed Resources: Projecting changes and risks to managed agriculture, water, land and energy systems

In 2024 we will continue our land- and water-systems modeling over Bangladesh, and conduct a suite of numerical experiments focused over coastal southwest Bangladesh at high spatial resolution as well as across all of Bangladesh at lower spatial detail. These efforts will incorporate our recent progress in linking our models that represent and respond to land-use change, and allow us to track tradeoffs between agriculture and aquaculture landscapes, as well as provide needed inputs for the development of an economic model of Bangladesh.

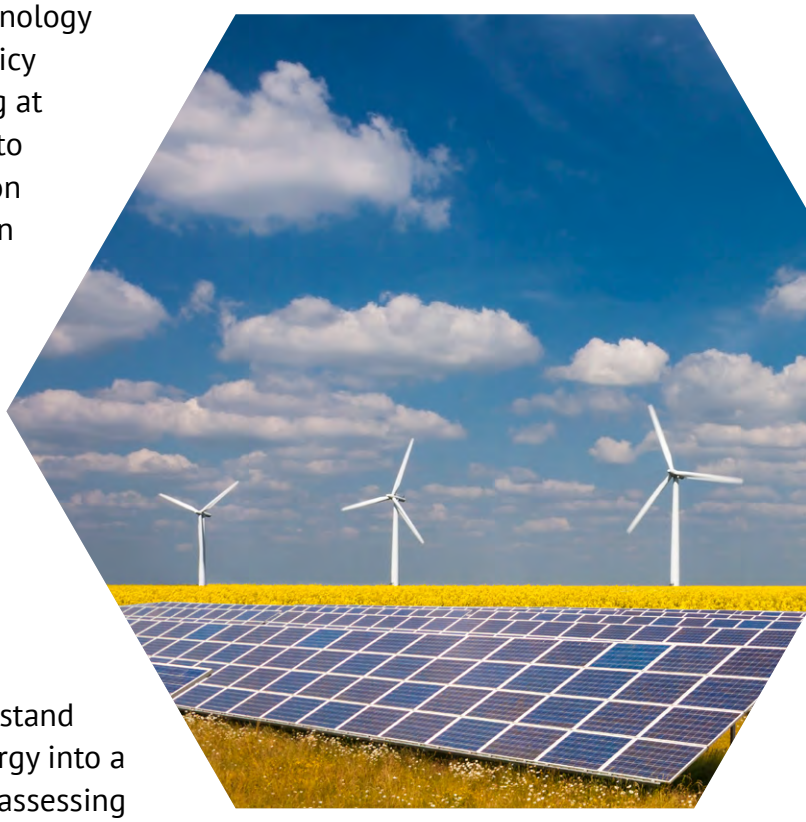
We will expand our ongoing studies of the co-evolving consequences and future pathways of land use, land management, and water availability and quality across 2,000+ basins covering the contiguous United States, with special attention to the Mississippi River Basin. These investigations will expand upon the stress tests on water quality and land-use projections that we recently completed.

Infrastructure & Investment: Projecting physical and transition risk, and adaptation and resilience to climate change and associated extreme events

In conjunction with our participation in the MIT Climate Grand Challenges project "Preparing for a new world of weather and climate extremes," we will continue our analyses of extreme events over South Africa and expand the initial analyses (which considered shifts in extreme extra-tropical cyclones) to assess the compounding effects of changes in droughts and their impacts on crop production and land-management decisions. In addition, we will assess the impact of extreme events on solar and wind power reliability and vulnerability. In other newly funded work, we will begin to assess how changing extreme environments will affect soil biogeochemistry and its capacity as a sink for global atmospheric hydrogen, and the consequences for leakage rates for a hydrogen-based energy system.

Energy Transition: Projecting the future energy mix nationally and globally, and prospects for different sectors and technologies

We will continue our analysis of low-carbon technology pathways under different energy and climate policy scenarios in a multi-sector, economy-wide setting at global and regional levels. In particular, we plan to assess sustainable aviation fuels, industrial carbon capture, hydrogen production and use, and carbon dioxide removal technologies such as bioenergy with carbon capture and storage, afforestation/reforestation, biochar, enhanced weathering of minerals, and direct air capture. Our researchers will pay special attention to the challenges of decarbonizing hard-to-abate sectors, such as aviation, iron and steel production, and cement production. We also will continue exploring global and regional biomass availability for transportation fuels.



Among other things, we will seek to better understand the challenges of integrating wind and solar energy into a dispatchable power generation mix; to continue assessing the land-use and food-price implications of bioenergy options and nature-based solutions such as reforestation and afforestation; to analyze the future of fusion energy in different world regions; and to explore issues related to the decarbonization of transportation, with a focus on air, water and land mobility. Finally, to enable analyses of a wide range of possible future outcomes, we will continue developing estimates for the costs of advanced energy technologies.

Policy Scenarios: Projecting global and regional environmental and economic change under different policies aimed at climate and air pollution mitigation and economic development

We will continue to explore emissions pathways aimed at achieving the Paris Agreement's short-term targets (Nationally Defined Contributions, or NDCs) and long-term goals (keeping global warming well below 2°C, and ideally 1.5°C). As part of this work, we will analyze the role of carbon dioxide removal technologies for reaching these and other climate targets. We also plan to enhance our Economic Projection and Policy Analysis (EPPA) model to include additional regions and sectors, thereby expanding our capability to study relevant regional and sectoral policies.

We plan to expand our capability to assess the impacts of border carbon adjustments (BCAs), trade policy instruments that impose charges on imports to reflect the regulatory costs imposed on domestically produced carbon-intensive products. We will assess the goals of BCAs for reducing greenhouse gas emissions and avoiding trade advantages and disadvantages as different governments enact climate policies with different levels of ambition. We also plan to assess the impacts of emissions-reduction policies on hydrogen use in the U.S. Finally, we will continue our assessment of scenarios to better quantify climate-related physical and transition financial risks.

Regional Analysis: Projecting sub-national, national and multi-national environmental and economic change under different policy scenarios

Our plans for 2024 include an in-depth analysis of climate-related policies in different countries and regions, and their environmental and economic impacts. We will enhance our studies of different regions of the U.S. We will also conduct an analysis of several countries of South America, including Brazil, Chile and Colombia, regarding their policies for and developments of sustainable aviation fuels. We will also investigate decarbonization pathways for major emitting regions such as the EU, China and India. Other regional analyses will explore decarbonization options in Canada and Taiwan, climate impacts on the economy of the U.S. and selected African countries, hydrogen production and use in different regions of the U.S., and transition risks in India.

Multi-Sector Dynamics: Exploring potential tipping points and transition states of Earth and human systems at regional to sub-regional scales

We will continue to upgrade our System for the Triage of Risks from Environmental and Socioeconomic Stressors (STRESS) platform with a focus on expanding its global mapping and combinatory metric capability. This will include providing projections of key economic and environmental conditions that are predicted under our IGSM scenarios. We will also develop and attempt to deploy a scenario-discovery toolkit designed to explore uncertainty and link key features/assumptions of the IGSM to extreme predicted outcomes. Meanwhile, we will initiate efforts to link the Joint Program's various data-visualization capabilities.

We will continue simulations and projections of land use, land productivity, managed water, and water quality across 2,000+ basins within the contiguous U.S. These model simulations will also be combined with simulations from our USREP model that represents energy-economics at state-level resolution, as well as a more spatially detailed representation (resolving scales at about 50km) of potential land-use changes. Finally, we will continue to develop our modeling framework and scenario-generation capabilities so that they may ultimately be used to identify optimal climate-health-equity targets.

MODELING SYSTEM

Our state-of-the-art models and analytical methods project global and regional changes and potential risks under different policy scenarios. Here we summarize the plans for the coming year to upgrade and expand our modeling system.

- Expand the Joint Program's data-visualization capabilities to include continued improvements to the System for the Triage of Risks from Environmental and Socioeconomic Stressors (STRESS), and a new scenario discovery tool that will allow for uncertainty and identify key factors that lead to extreme outcomes.
- Document and demonstrate the latest advance in the Earth-system model component of the IGSM, which will feature the Community Earth System Model (CESM).
- Create a country-specific, economy-wide multi-sector model of Bangladesh to study the impacts of climate change on the Bangladesh economy.
- Expand representation of sustainable aviation fuel pathways in the MIT Economic Projection and Policy Analysis (EPPA) model.
- Expand representation of carbon dioxide removal options in the EPPA model.
- Update the base-year economic dataset (Global Trade Analysis Project, GTAP) for the EPPA model.

MIT JOINT PROGRAM ON THE SCIENCE AND POLICY OF GLOBAL CHANGE

Our work is funded by an evolving, international consortium of government, industry and foundation sponsors and contributors. Those listed below provided financial support in 2023.

Federal Sponsors

- Millennium Challenge Corporation [MCC]
- U.S. Department of Energy [DOE]
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- U.S. National Science Foundation [NSF]
- U.S. Congressional Budget Office [CBO]
- U.S. Environmental Protection Agency [EPA]
- Nat'l Aeronautics & Space Administration [NASA]

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- Murphy Oil
- The G. Unger Vetlesen Foundation

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- Exxon Mobil
- IFP Energies Nouvelles
- J-Power
- LATAM Airlines
- MathWorks
- MIT Energy Initiative (MITEI)
- MITEI Future Energy Systems Center Consortium
- MIT International Science and Technology Initiatives (MISTI)
- MIT Office of the Vice President for Research: Climate Grand Challenges
- Morgan Stanley
- National Petroleum Council (via MITEI)
- Novartis
- Shell

Report designed by Jamie Bartholomay