2022 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

As the world simultaneously confronts multiple crises—a pandemic, war, climate extremes, supply chain disruptions and inflation, among others—we remain committed to improving our understanding of global and regional change challenges. To address these challenges, we are identifying science-based, sustainable solutions, and disseminating those solutions to decision-makers in the public and private sectors. Thanks to the ongoing financial support and engagement of our Program Sponsors and Contributors, we continue to pursue actionable, leading-edge research on several critical global and regional change issues.

A number of our studies this past year have provided guidance for decision-makers seeking to achieve net zero emissions by 2050 in alignment with the Paris Agreement long-term goal of keeping global warming well below two degrees Celsius. We helped to develop a noteworthy roadmap of the needed energy and technology choices, and while showing that there are multiple pathways to reach the 2050 target, we identified those that can be implemented equitably.

Meanwhile, we developed a new model—the Tool for Air Pollution Scenarios (TAPS)—to coordinate climate and air-quality policies so as to maximize public health benefits. We also released our Socio-Environmental Systems Risk Triage (SESRT) platform, which draws on multiple data streams to pinpoint compounding environmental and economic risks in the continental United States; and the latest version of our Economic Projection and Policy Analysis (EPPA) model.

In the coming year, we plan to: upgrade our MIT Earth-System Modeling (MESM) capability through the use of new satellite data and higher-resolution spatial representation of Earth-system components; expand TAPS to allow for a more comprehensive exploration of climate and health targets; broaden the SESRT platform to cover the globe and project future risk; and enhance the EPPA model to enable policy studies of additional regions and economic sectors.

Among other things, we will continue efforts to produce a large ensemble of simulations and projections of land and water resource use across more than 2,000 drainage basins within the contiguous U.S. And last but not least, we will conduct a comprehensive analysis of today's dynamic geopolitical situation by designing new scenarios that account for recent global energy system changes emerging from the war in Ukraine.

Again, we are grateful to our many Sponsors and Contributors for making this work possible. As we begin to pursue the plans for 2023 highlighted below, 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 2022

RESEARCH HIGHLIGHTS

Research Focus Areas

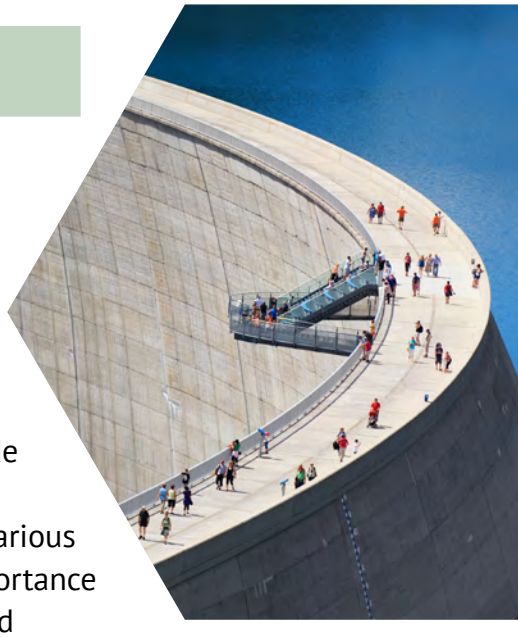
The Program's core research focus areas center on projected global and regional changes and potential risks under different policy, economic and technology scenarios. Here we present highlights of the past year's progress for each research focus area.

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

At the core of the Joint Program's 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 this suite of Earth-system modeling tools in 2022, we incorporated machine-learning improvements in model-based estimates of evapotranspiration used in Earth-system models. We also identified important nutrient relays in the global oceans and their importance at sustaining ocean productivity across the subtropics, and constructed new estimates of historical global riverine discharge of nutrients and carbon into the global oceans that highlight the importance of terrestrial fluxes in global-ocean biogeochemistry models for the accurate simulation of coupled ocean carbon cycling, biogeochemistry and ecology. We exercised data-assimilation methods to quantify the recent growth in the atmospheric concentration of nitrous oxide and natural methane emissions—two of the most potent greenhouse gases. Finally, using both machine-learning and explicit models, we provided novel perspectives on the connections that link air quality (as well as pollutant and aerosol transports) to weather events and climate variations (e.g., air quality under changing meteorological conditions and in the Global South; atmospheric mercury trends; optimizing stratospheric aerosol geoengineering).

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



Over the past year, we explored opportunities to optimize hydropower infrastructure by promoting electricity trade among power pools across sub-Saharan Africa, showed that confidence in anticipated water allocations can be substantially impeded by the uncertainty of future hydro-climates, and used our suite of IGSM-MESM hydro-climate scenarios to support risk-based assessments of potential climate-related impacts on global food production. We also tapped our extensive set of IGSM climate-change ensembles to provide a global risk-based assessment of anticipated trends in wind power resources, and contrasted the spatial features of these trends across various emission scenarios, seasons and locations. In view of the growing importance of intermittent renewables in future energy systems, we developed and tested an economic dispatch model showing how in Brazil, existing hydropower production can be used as a reliable backup for intermittent renewable-energy production.

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

Our work continues to employ machine-learning and empirically-based downscaling methods that allow for more granular and local-scale assessments of future risks associated with extreme events. Over the past year, our assessment of flood risks in Cambridge, Mass. associated with summertime events with heavy-to-extreme rainfall intensities indicated weak evidence of any significant trends in the near term, but also highlighted the challenges at projecting changes with high confidence for such events due to insufficient data. Our process-based modeling tools produced an assessment of health risks in India associated with crop residue burning and downwind transport, and what mitigation strategies can be employed to reduce premature deaths. We also applied these modeling tools to show how rising wildfire emissions in the past decade have contributed to the increase in nitrogen dioxide concentrations over the western U.S. Finally, we explored transition risks associated with climate change policy driven by (1) policy ambition and timing and (2) the pace and availability of new technologies, and identified substantial transition risks to stranded assets in unrealized fossil fuel production.

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

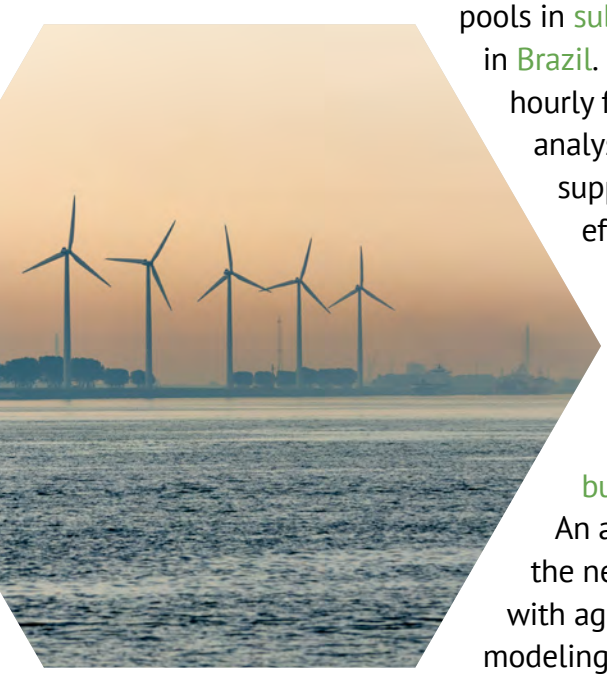
Our research helped enable decision-makers to make sound, forward-looking choices from an expansive menu of technology and policy options aimed at lowering greenhouse gas emissions. We continued to develop and use scenarios of energy transition and their impacts on economy, emissions and the environment, 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 hard-to-abate sectors such as cement, iron and steel, aviation and shipping. Finally, recognizing the importance of distributional impacts as a consideration in climate policy design, we evaluated different pathways to a just energy transition by exploring tradeoffs between the equity and efficiency of different revenue recycling schemes.

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. In that same vein, we continued to advance a human-technical-environmental systems framework for sustainability analysis. Our policy scenario explorations also included modeling the impacts of mercury, crop residue burning and smoke exposure; assessing the plastic intensity of U.S. industries; and evaluating the impacts of climate change on crop growth and production, which may undermine the resilience of the global food system; and estimating the economic value of stranded assets under various emissions mitigation scenarios. Finally, we updated our EPPA model and refined our understanding of when and how to use such models in environmental policy analysis.

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 electricity trade impacts on regional power pools in sub-Saharan Africa, and the economic dispatch of power generation in Brazil. In both studies, we found that existing hydro capacity provided hourly flexibility to backup intermittent renewables. Our economic analysis of hard-to-abate sectors in India included different policy support options such as natural gas support, increased resource efficiency, and carbon pricing. Our estimation of the impacts of U.S. wind power on air quality and pollution exposure illustrated the benefits of federal investments for disadvantaged communities, but illuminated the need for more targeted measures to mitigate pollution disparities among racial and income groups. Our study of air quality impacts of crop residue burning in India also showed the need for targeted interventions. An assessment of mercury concentrations in the Arctic underscored the need for more ambitious action as mercury deposition declines with aggressive reduction measures. In other work, we explored modeling frameworks for financial stress testing in South Africa.



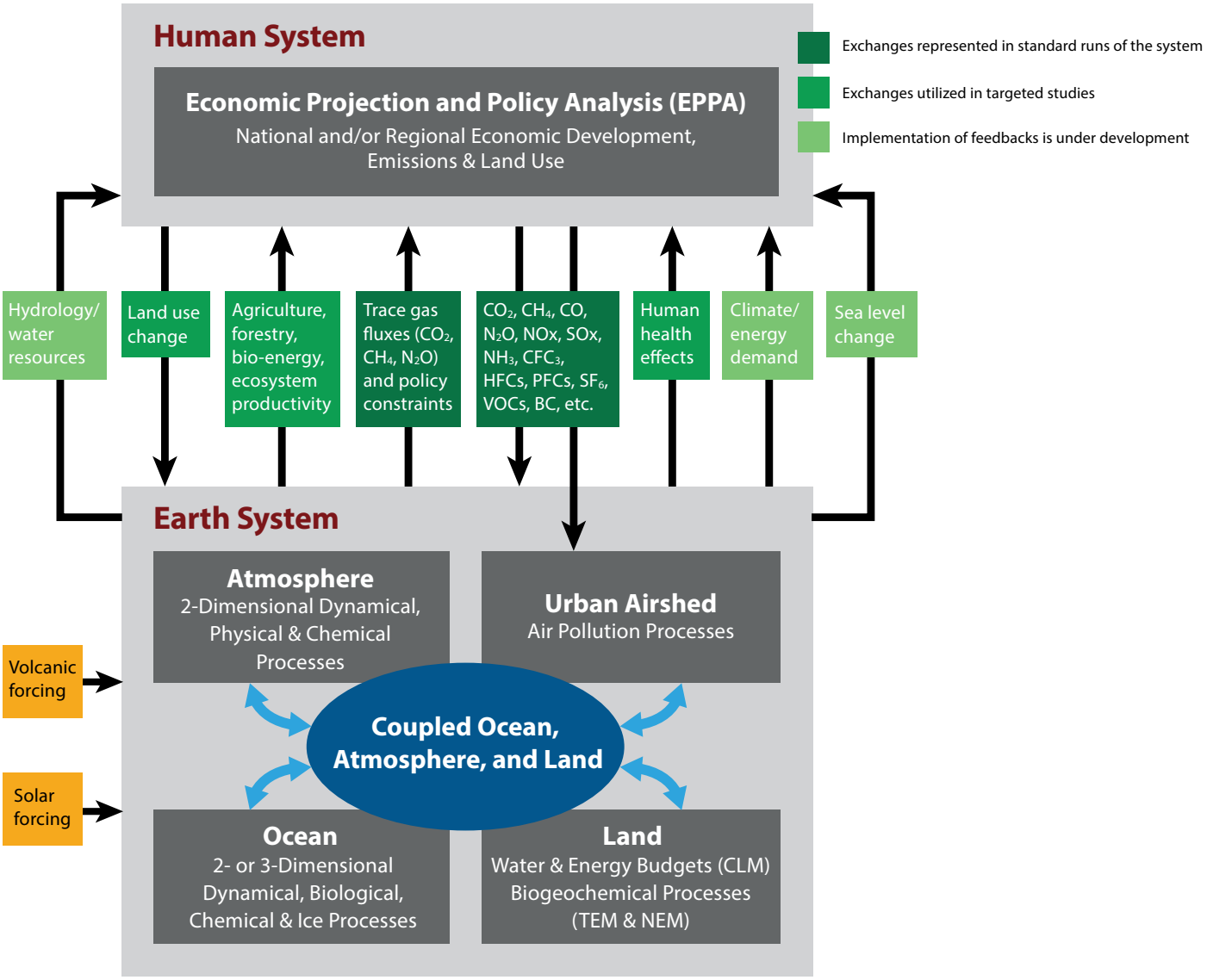
Multi-Sector Dynamics: Exploring potential tipping points and transition states of Earth and human systems at regional to sub-regional scales

Given the multi-disciplinary underpinnings of multi-sector dynamics (MSD), we continued to actively collaborate with the scientific community, and contributed to the formal description of its core scientific definitions and concepts. In so doing, we identified new perspectives on uncertainty and risk-based analytic approaches, and provided "best practice" recommendations for MSD research. We also continued to advance our in-house modeling capabilities in order to enable MSD scenario exploration. Our MSD work also focused on the representation of uncertainty through a "scenario discovery" context, resulting in the development of a visually-based inspection tool that identifies numerous MSD pathways to achieve any successful energy transition goal. Finally, we released our inaugural version of the "Socio-Environmental Systems Risk Triage" (SESRT) platform. The SESRT is a publicly available platform that brings together data across socio-environmental systems, economics, demographics, health, biodiversity and infrastructure. These data are then cast into a portfolio of metrics that (1) convey physical and transition risks and (2) may be further combined with additional metrics conveying inequities and other demographic information to highlight "hotspots" of co-existing and compounding risks.

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:

- Launching the inaugural version of the "Socio-Environmental Systems Risk Triage" platform
- Developing large-ensemble data to support our climate-related impact assessments
- Documenting a new version of the EPPA model in peer-reviewed literature
- Creating a tool for air pollution scenarios to enable studies of climate and air quality policies



PUBLICATION HIGHLIGHTS

Can the world meet global climate targets without coordinated global action?

Growing demand for an energy transition could move the needle, but not far enough

Absent legislative victory, the President can still meet U.S. climate goals

Activating a Clean Air Act provision could deliver major climate, health and economic benefits

What choices does the world need to make to keep global warming below 2°C?

New study reveals multiple pathways for a successful energy transition by 2050

Six leading models agree: Rapid decarbonization of power, transportation sectors key to a successful energy transition

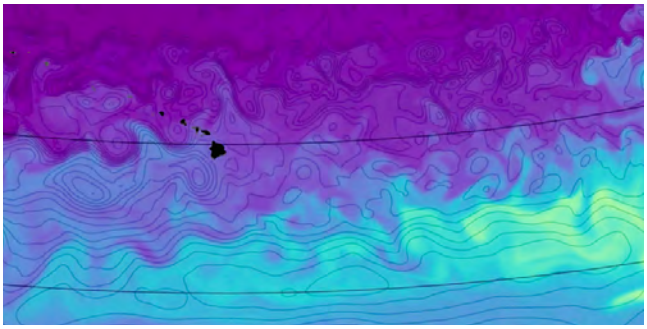
Study maps path to 2030 U.S. climate target of at least 50% greenhouse gas emissions reduction

Getting the carbon out of India's heavy industries

Study highlights pathways to cut emissions, lower climate and health risks

Stranded assets could exact steep costs on fossil energy producers and investors

Study estimates potential losses by 2050 amid low-carbon energy transition



Small eddies play a big role in feeding ocean microbes

Swirling waters replenish nutrients in open ocean, a new study finds, and could mitigate some climate change effects (MIT News)

PHOTO SOURCE: AGU

AGU Fall Meeting frames science as engine of a better future

MIT Joint Program presentations showcase tools and pathways to assess and alleviate regional and global risk

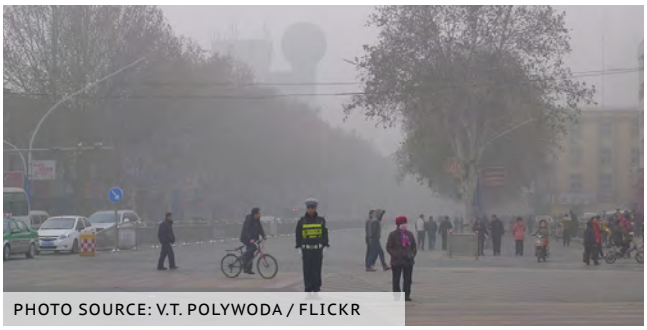


PHOTO SOURCE: V.T. POLYWODA / FLICKR

Coordinating climate and air-quality policies to improve public health

New tool pinpoints policy combinations that maximize health benefits

A targeted approach to reducing the health impacts of crop residue burning in India

Study shows how small-scale actions could improve air quality and health outcomes

A healthy wind

Health benefits of using wind energy instead of fossil fuels could quadruple if the most polluting power plants are selected for dialing down, new study finds (MIT News)

Links to 2022 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 outlets that have covered Joint Program activities include:

Associated Press
Bloomberg
Boston Business Journal
Boston Globe
Canary Media
Climate Feedbacks
The Conversation
E&E News
Earth.org
Fast Company
Fortune
HealthDay
The Hill
Institutional Investor
MarketWatch
Men's Journal
NBC-Boston
National Observer
Net Zero Investor
Pensions and Investments
Power Electronics News
Technology Review
Trends MENA
UNFCCC
US News & World Report
The Verge
WBUR
Washington Post
White House
Yahoo!
Yale Climate Connections

News Stories

How the industry's fastest growing sector is pushing managers to change their behavior

Wellington, Schroders and others are taking a more activist approach to managing their environmentally-sustainable funds (Institutional Investor, Pensions & Investments)

Report: Corporate climate pledges are weaker than they seem

MIT Joint Program Co-Director Emeritus John Reilly suggests some avenues for improvement (Associated Press, Washington Post)

White House releases white paper on how better modeling of broader economic impacts of climate change can help quantify economic and fiscal impacts of climate change and climate action

Council of Economic Advisers/OMB white paper highlights MIT Joint Program's EPPA and USREP as model examples (pp. 25-26) (White House)

Can electric vehicles decarbonize transportation?

In the United Nations Climate blog Electric Future, MIT Joint Program Deputy Director Sergey Paltsev highlights challenges in making EVs truly emissions-free (UNFCCC)

Are EVs driving towards greener world or uncertainty?

Recent studies suggest that electric vehicles may not eliminate all emissions even by 2050, particularly those related to mining and battery production (TRENDS MENA)

Why an energy crisis and $5 gas aren't spurring a green revolution

As high prices move consumers to rethink their attachment to oil and gas, America is struggling to meet the moment (Washington Post, E&E News)

Hacking Climate Change

This special report on MIT's Climate Grand Challenges initiative looks at how the Institute's problem solvers—including the Joint Program, which is contributing to three of its five flagship projects—are stepping up to help save the planet from the devastating effects of global warming. (Technology Review, Boston Globe, Bloomberg, WBUR, NBC-Boston)

US solar and wind projects stalled in Q2. What happened?

The Auxin Solar tariff investigation and uncertainties around tax incentives tanked progress, according to a new American Clean Power report (Canary Media)

The climate bill won't stop global warming. But it will clean the air.

MIT's Noelle Selin and John Sterman comment on potential air quality and climate benefits (Washington Post)

Extreme heat in the US, Europe and China is slamming economies around the world—and making inflation worse

Extreme events are contributing to high prices, says MIT Joint Program Deputy Director Sergey Paltsev (Fortune, Yahoo!)

Losses from fossil fuel stranded assets 'could reach $30.6tn'

A new study has estimated that the global net present value (NPV) of stranded assets in fossil fuels could be $30.6tn under a scenario where net zero is achieved by 2050 (Net Zero Investor)

Future renewable diesel plant will turn food crops into fuel

MIT Joint Program's John Reilly touts grasses as a more sustainable biofuel alternative than food crops (National Observer)

Different parts of the planet warm more quickly than others. That doesn't mean climate change isn't happening.

MIT Joint Program Deputy Director C. Adam Schlosser helps explain regional variations in warming (Climate Feedback)

Water Crisis in South Africa: Causes, Effects, And Solutions

Report cites MIT Joint Program study projecting significant water-supply risks by 2050 (Earth.org)

BEVs and FCEVs Can Meet Paris Agreement Goals

Policymakers and manufacturers are working toward building new technologies to reduce the carbon footprint of cars (Power Electronics News)

Wind power is bringing Americans real health benefits

MIT Joint Program faculty affiliate Noelle Selin shows how to maximize them (US News & World Report /HealthDay, The Hill; The Verge)

'I was just blown away': State report shows climate change will take massive toll on Mass. without urgent action

MIT Joint Program Deputy Director C. Adam Schlosser served on report's Climate Science Review Panel; Research Scientist Kenneth Strzepek served on its Climate Assessment Consultant Team (Boston Globe)

How Fully (Un)prepared Is America for a Supercharged Electric Vehicle Rollout in the Near Future?

MIT Joint Program Deputy Director Sergey Paltsev notes need to further reduce emissions associated with EV production and power sources (Men's Journal)

Commentaries

The 1.5 degrees goal: Beware of unintended consequences

The 1.5° goal can be a 'useful spur to action,' but it's not a make or break point. Importantly, each 0.1-degree increase avoided is 'cause for celebration and hope.' (Yale Climate Connections)

Fighting climate change in a fragmented world

Why it's important for U.S. scientists to sustain engagement with their Chinese and Russian peers (The Hill)

Here's how to meet Biden's 2030 climate goals and dramatically cut greenhouse gas emissions – with today's technology

MIT Joint Program Co-Director Emeritus John Reilly lays out 'doable and affordable' policy roadmap (The Conversation) (Republished in MarketWatch and Fast Company)

Extreme heat kills inequitably: Reflective pavements can help, but city action is required

Commentary cites Joint Program Report on the climate mitigation potential of U.S. urban infrastructure albedo enhancement (The Hill)

PROJECT HIGHLIGHTS

New Projects

MIT announces five flagship projects in first-ever Climate Grand Challenges competition

Joint Program researchers are participating in three of the five projects. (MIT News)

- Bringing Computation to the Climate Challenge
- Preparing for a new world of weather and climate extremes
- The Climate Resilience Early Warning System

PHOTO SOURCE: MIT CLIMATE GRAND CHALLENGES

Biomass availability for producing transportation fuels

Sponsor: MIT Energy Initiative (MITEI) Future Energy Systems Center
Duration: 2 years
Leaders: Sergey Paltsev, Kristala Prather (MIT Chemical Engineering)

Global Outlook for Fusion Energy Deployment

Sponsor: Eni (via MITEI)
Duration: 16 months
Leader: Sergey Paltsev

Development and applications of GEOS-Chem atmospheric chemistry in CESM and MUSICA

Sponsor: U.S. National Science Foundation (NSF)
Duration: 3 years
Leaders: Sebastian Eastham; Daniel Jacob (Harvard University), Louisa Emmons (UCAR)

Renewed Projects

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

Sponsor: NASA
Duration: 5 years
Leader: Ronald Prinn

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

Sponsor: U.S. Department of Energy (DOE)
Duration: 5 years
Leaders: Ronald Prinn, Adam Schlosser, Sergey Paltsev, Jennifer Morris

Published papers include:

- Uncertainty analysis in multi-sector systems: Considerations for risk analysis, projection, and planning for complex systems
- Assessing Compounding Risks Across Multiple Systems and Sectors: A Socio-Environmental Systems Risk-Triage Approach
- MultiSector Dynamics: Advancing the science of complex adaptive human-Earth systems
- Representing socio-economic uncertainty in human system models

Ongoing Projects

Carbon Capture and Storage (CCS) Assessment Project

Presented paper at the International Conference on Greenhouse Gas Control Technologies

Economic analysis of the Hard-to-Abate Sectors in India

Published paper in *Energy Economics*

U.S. Regional Energy Model

Published papers include:

- Actions for reducing US emissions at least 50% by 2030
- Meeting U.S. greenhouse gas emissions goals with the International Air Pollution Provision of the Clean Air Act

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:
XLV (45th) MIT Global Change Forum
March 23–24, 2023

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

Sessions:

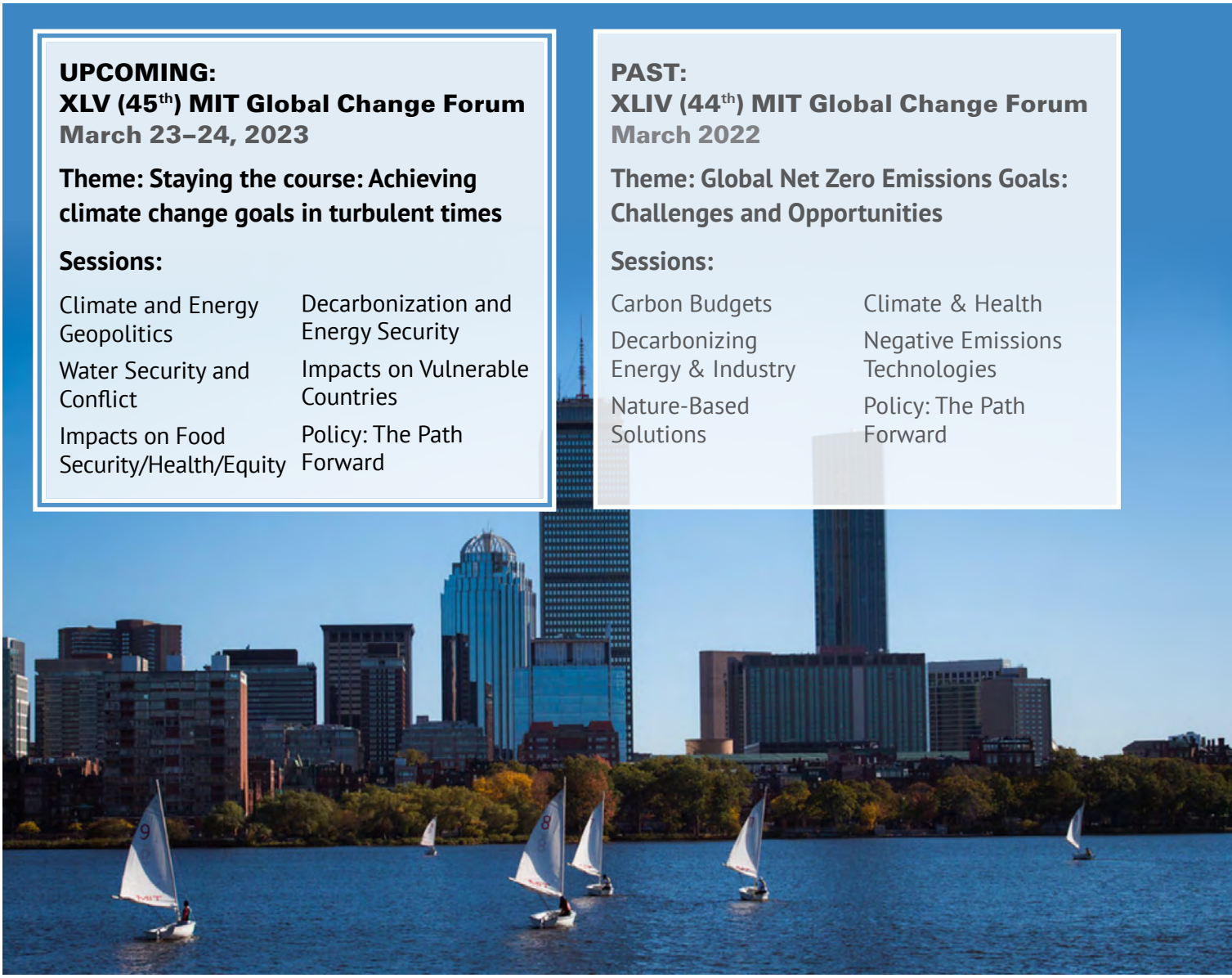
- Climate and Energy Geopolitics
- Decarbonization and Energy Security
- Water Security and Conflict
- Impacts on Vulnerable Countries
- Impacts on Food Security/Health/Equity
- Policy: The Path Forward

PAST:
XLIV (44th) MIT Global Change Forum
March 2022

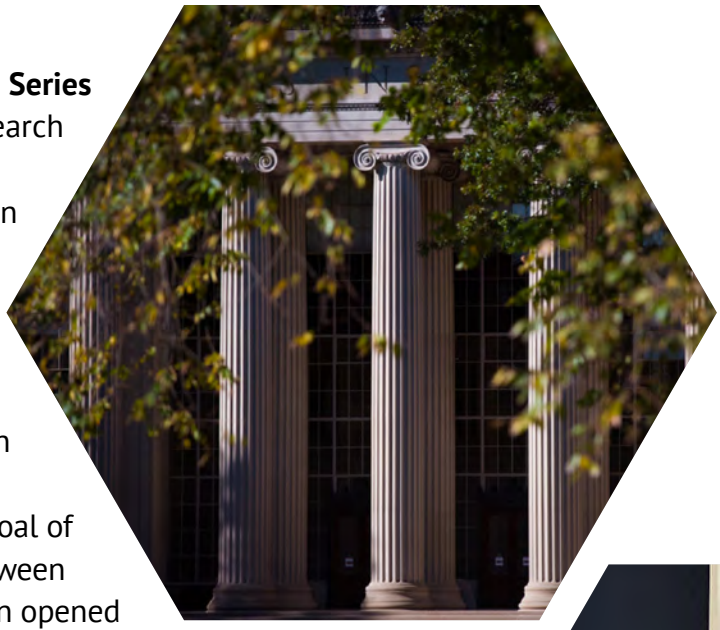
Theme: Global Net Zero Emissions Goals: Challenges and Opportunities

Sessions:

- Carbon Budgets
- Climate & Health
- Decarbonizing Energy & Industry
- Negative Emissions Technologies
- Nature-Based Solutions
- 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.

Nature-Based Solutions for Accelerating Climate Action. Co-organized by the Joint Program and Imperial College London. Each of three sessions focused on a particular dimension of nature-based climate mitigation projects (ecological, socioeconomic or financial), with a goal of facilitating a search for integrated solutions between practitioners with diverse expertise. Each session opened with short talks by experts in the relevant domain, who provided their perspective on the greatest challenges facing the implementation of nature-based solutions. This was followed by a group discussion.

Pathways for Agriculture, Forestry and Other Land Use (PAFOLU) in Support of Sustainable Development, Equitable Solutions and a Stable Climate. Co-organized by the Joint Program, IFPRI and Oxford University. Experts across multiple institutions and stakeholders from industry, government and non-profit sectors came together to jointly identify important knowledge priorities as well as means for meeting these priorities. The workshop addressed global issues in climate, sustainability, mitigation and AFOLU-based solutions—but also brought these issues down to continental and national foci on Africa, which is expected to undergo rapid development and population growth in the coming decades.

Webinars

Our webinar series provides short, online-accessible explorations of topics of interest to our sponsors and stakeholders.

Affordable Direct Air Capture: Myth or Reality? Co-organized with the MIT Laboratory for Aviation and the Environment as a hybrid (MIT Campus/Zoom), campus-wide event, this webinar explored the economic feasibility of large-scale DAC, featuring presentations by two trailblazers in carbon-removal technology—MIT Energy Initiative Senior Engineer Howard Herzog and Harvard University Professor of Applied Physics David Keith, founder of Carbon Engineering. Moderated by MIT Joint Program Founding Co-Director and Sloan School of Management Professor Emeritus Henry Jacoby, and introduced by LAE Director and MIT Aero/Astro Professor Steven Barrett.

Individualized Workshops and Webinars

Economic projection and policy analysis (Congressional Budget Office)

Energy demand scenarios (Norwegian Ministry of Petroleum and Energy)

Cement industry decarbonization (Shell)

The *MIT Global Change Outlook* (Manulife)

Climate change mitigation pathways (TotalEnergies)

Risk-triage screening platform (Novartis)

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.

Where were Joint Program researchers in 2022?

Events:

AGAGE Meeting of Scientists and Cooperating Networks

AGU Fall Meeting

AIAA 2022 SciTech Forum

Anant Fellowship for Climate Action - Anant National University

Annual Conference on Global Economic Analysis

ANUFOOD BRAZIL 2022 CONGRESS

AMOS Annual Conference

Boston University Biogeoscience Seminar Series

Carnegie Institute Ecosystem Seminar Series

CEEPR European Energy Policy Conference

CEEPR Int'l Energy Policy Conference

Cell Press Beijing Conference

CERAWeek

CESM Workshop

COP27

EMF 37: Deep Decarbonization & High Electrification Scenarios for North America

EU Clean Aviation Joint Undertaking Workshop

Greenhouse Gas Control Technologies Conference

GTAP Conference: the 25th Annual Conference on Global Economic Analysis

IFPRI-Oxford-MIT workshop "Pathways to Development and a Stable Climate"

Industrial Climate Technology Summit

International GEOS-Chem Conference

International Ocean Colour Coordination Group annual committee meeting

Margalef Symposium

MIT Climate and Sustainability Consortium Workshop

MIT Energy Initiative Fall Meeting

MITEI Future Energy Systems Center

MIT Global Change Forum XLIV

NASA Aeronautics Space and Engineering Board 170th Meeting

ProSyn Fest

Snowmass Climate Change Workshop

Taiwan Economic Association Annual Conference

Trait-based Approaches to Marine Life Workshop

WiNDC Workshop "Trade Climate Policy and Income Distribution"

WMO-UNEP Forum on Gaps in GHG/ ODS Monitoring

Committees, Councils, and Working Groups:

Decade of Agriculture Initiative - US Farm and Ranch Alliance Science Advisory Council

Earth's Future journal special section: Modeling MultiSector Dynamics to Inform Adaptive Pathways

Federal Climate Scoring Project Task Force (Brookings Institute)

International Civil Aviation Organization - Committee on Aviation Environmental Protection - Fuels Task Group

IPCC Working Group (Chapter 3)

MIT Course Instructor

MulitSector Dynamics (MSD) Community of Practice (CoP) - Scientific Steering Group

MSD CoP - Uncertainty Quantification and Scenario Discovery Working Group

MSD CoP - Human Systems Modeling Working Group

MSD-LIVE Stakeholder Group

MultiSector Dynamics (MSD) monthly leadership calls

NSF Food, Energy, and Water System project Stakeholder Working Group: Climate-induced Extremes on the Food, Energy, Water Nexus and the Role of Engineered and Natural Infrastructure

Peer review provided for:

25th Annual Conference on Global Economic Analysis

Artificial Intelligence for the Earth Systems

Atmospheric Research

Climate and Atmospheric Science

Energy Economics

Energy Policy

Environmental Modelling & Software

Environmental Research Letters

Global Environmental Change

iScience

Journal of Hydrology

MISTI GcvSF Scientific Review Committee

Nature Climate Change

Nature Communications

Sustainability Science

The Sao Paulo Research Foundation

Water Resources Research

Other Presentations:

Antofagasta Minerals

Bouygues

Citi Group

ClarkeModet

Council of Economic Advisers/Office of Management & Budget

Eneos

European Investment Bank

Electricite de France

Fundacion Ramon Areces

Mitsui

Nuclear Innovation Alliance

Saudi Electricity Company

University of Illinois at Urbana-Champaign

US Department of Energy

US Federal Reserve

X-Company

Online Outreach

The MIT Joint Program partnered with MIT Video Productions to release four mission-focused videos in conjunction with Earth Day 2022:

- Program Overview: Short version (3.5 minutes). Long version (5.5 minutes).
- Greenhouse Gamble Wheels (1 minute). Roulette-style spinning wheels each represent a different set of greenhouse gas policies. Colored slices show the likelihood of temperature change in varying ranges. For more information, see the Greenhouse Gamble webpage.
- Multi-Sector Dynamics Modeling Tool (1 minute). This open-science visualization platform combines, overlays and diagnoses landscapes of socioeconomic, health and environmental risk and injustice. For more information, see the Multi-Sector Dynamics webpage.

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.

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
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ADMINISTRATIVE HIGHLIGHTS

The work of the MIT Joint Program combines the efforts and expertise of its two parent organizations—the Center for Global Change Science (CGCS) and the Center for Energy and Environmental Policy Research (CEEPR)—as well as the MIT Energy Initiative (MITEI).

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 2022 include:

- Major upgrade of the svante cluster that we use extensively in our research, raising the compute-capacity from 75 to 100 nodes.
- Compute nodes upgraded to a low-latency HDR infiniband network.
- We maintain nearly double the physical cores, now 3,300 cores (up from 1,700 in 2021).
- We now maintain 12 high-capacity file-server units (up from 10 in 2021).
- Data-storage capacity upgraded to 4 petabytes (PB) (a 1 PB increase from 2021).

Membership

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

During 2022, the Joint Program was supported by 31 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 2022 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

Sadia Afrin • Postdoc • Modeling regional-scale air quality and health impacts.

Sandeep Chinta • Postdoc • Applying machine learning to methane biogeochemistry modeling.

Sebastian Eastham • Principal research scientist • Transferred into the Joint Program

Aryeh Feinberg • Postdoc • Studying atmospheric mercury uptake by vegetation.

Jennifer Morris • Principal research scientist • Promoted

Shelli Orzach • Completed two years of assembling data for our risk-triage platform.

Anthony Wong • Postdoc • Assessing the impact of alternative fuel usage in global shipping.

Visitors to the program

Lorenzo Campagnolo • Researcher, Ca' Foscari University of Venice, Italy • Modeled distributional impacts of climate change.

Lucas Desport • PhD student, MINES ParisTech • Modeled hydrogen and carbon capture.

Shray Mather • Scholar, Birla Institute of Technology and Science, India • Applied machine learning techniques to satellite data.

Kilian Rouge • PhD student, Ecole Polytechnique • Investigated composite biodiversity indicators.

Dominic White • PhD student, Auckland University of Technology • Improved representation of land-use change in integrated assessment models.

Completed Student Work

The impact of climate change on human health. Will Atkinson, MS [Noelle Selin, Adam Schlosser]

Assessing the role of top-down techniques for improving regional estimates of artisanal and small-scale gold mining. Thandolwethu Dlamini, MS [Noelle Selin]

Policy design and institutional management of air pollution in China. Mengying (Mandy) Wu, PhD [Valerie Karplus]

Air quality-related health and equity implications of US decarbonization policy. Paul Picciano, MS [Noelle Selin, John Reilly]

Decarbonizing the global shipping industry: Evaluating pathways for alternative fuels. Tara Hong, MS [Sergey Paltsev]

Continuing Student Work

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

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

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

PLANS FOR 2023

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

In the coming year, we plan to initiate a long-term effort to considerably expand our Earth-system modeling capability. The goal of this effort is to quantitatively represent the inter-related, multi-dimensional structure of uncertainty in the Earth-systems' response to anthropogenic drivers (i.e., emissions and land-use changes). To that end, we will incorporate a more spatially detailed Earth-system model, as well as update observational data and develop additional metrics to determine the "acceptable" model responses and parametric values sampled. 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 refine our machine-learned estimates of natural methane emissions that can inform and improve our process-based modeling of terrestrial ecosystems. We will also continue to expand the capacity of our Tool for Air Pollution Scenarios (TAPS) model component by embedding it into the IGSM framework, which will allow for a more comprehensive exploration of climate and human-health targets.

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

In 2022 we plan to use our modeling and analysis tools to focus on current and future land productivity over Bangladesh, whose managed resources are at high risk for climate impacts. This research will consider not only cultivated lands but also the maintenance and potential expansion of mangrove plantations to serve both as natural barriers for storm-surge and sea-level rise threats and as a valuable carbon sink. These efforts will also assist in our algorithm development that projects potential land-use change and the trade-offs between agriculture and aquaculture landscapes, as well as provide needed inputs for the development of an economic model of Bangladesh.

In other work, we will continue our high-priority studies of the consequences and future pathways of land use, land management, and water availability and quality across 2,000+ basins covering the contiguous U.S., with special attention to the Mississippi River Basin. These investigations will likely provide valuable insights into potential upstream-downstream consequences of mitigation and adaptation actions that may be required to cope with multiple risks across the land, energy and water resource sectors that evolve as a result of human-forced changes.

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

We plan to continue multiple, collaborative studies aimed at advancing our machine-learning, analogue-based approaches to producing local-scale assessments of extreme/damaging weather events. In one study, we will focus on extreme events that adversely affect port operations at Durban and Port Elizabeth, South Africa. This work will include assessments of model fidelity at reproducing these events under the current climate, and we will extend this analysis to inform the confidence of projections in future changes under a range of human-forced future climates. We will pursue similar studies focused on Bangladesh and the contiguous U.S. to support our investigations of risks to managed resources.

We will also apply our analytic methods to build upon our projections of future wind and solar power resources, but with a focus on assessing potential changes in intermittency and extreme/damaging events. Any future energy scenario that requires extensive transition to low-carbon, intermittent energy technologies must consider the weather- and climate-related risks from extremes, the extent that these may change in the future, and what changes are unavoidable and must be factored into energy-capacity estimates, deployment strategies and technical specifications to ensure system-wide resiliency.

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 industrial carbon capture, hydrogen production and use, and negative emissions technologies such as bioenergy with carbon capture and storage, 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 plan to explore 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 use of hydrogen and carbon capture in steelmaking 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). As part of this work, we will analyze the role of net-zero emissions targets and negative emissions 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 plan to conduct a comprehensive analysis of today's dynamic geopolitical situation by designing new scenarios that account for recent global energy changes triggered by Russia's invasion of Ukraine. We also plan to emphasize the 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 2023 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 United States. 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 Norway and Singapore, economy-wide benefits from investments in water security in Indonesia, bioenergy and deforestation reduction tradeoffs in Brazil, and decarbonization pathways in Taiwan.

In support of all these regional investigations, we will continue to expand our risk-triage platform. We will continue to incorporate additional information for the U.S. as it becomes available. In addition, we intend to expand this platform to provide risk-triage analyses and visualization capabilities across all regions of the globe.

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 Socio-Economic Systems Risk Triage (SESRT) platform, expanding both its supporting data collection and its capabilities, with a focus on adding several human health and biodiversity metrics. In addition, we will begin incorporating projections from our IGSM scenarios into a new branch of the platform that will convey scenarios of future physical and transition risks, and provide combinatory metrics that will convey equity and just transitions. The platform will also be expanded to include a capability for global coverage of various risk metrics.

We will continue efforts aimed at producing a large set of 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 paralleled with simulations from our USREP model that represents energy-economics at state-level resolution. We will also continue to develop our model framework and scenario-generation capabilities that will 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 Socio-Environmental Systems Risk Triage (SESRT) platform to include: future projections of key metrics; global coverage mapping; additional metrics; and a "report card" summary for a selected area of interest.
- Begin efforts that enhance the MIT Earth System Model's (MESM) spatial resolution as well as uncertainty-quantification assessments to utilize the most recent observational data.
- Create customized versions of the MIT Economic Projection and Policy Analysis (EPPA) model to focus on Bangladesh, Chile, Peru, Ecuador and Colombia for specific projects.
- Expand representation of carbon dioxide removal options in the EPPA model.
- Expand sectoral representation of EPPA to model decarbonization pathways in aviation and shipping.
- Finalize a new version of the U.S. Regional Energy Policy (USREP) model to employ the base-year data from the publicly available dataset WinDC.

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 2022.

Federal Sponsors

- Congressional Budget Office [CBO]
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- U.S. Department of Energy [DOE]
- Federal Aviation Administration [FAA]
- National Science Foundation [NSF]

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