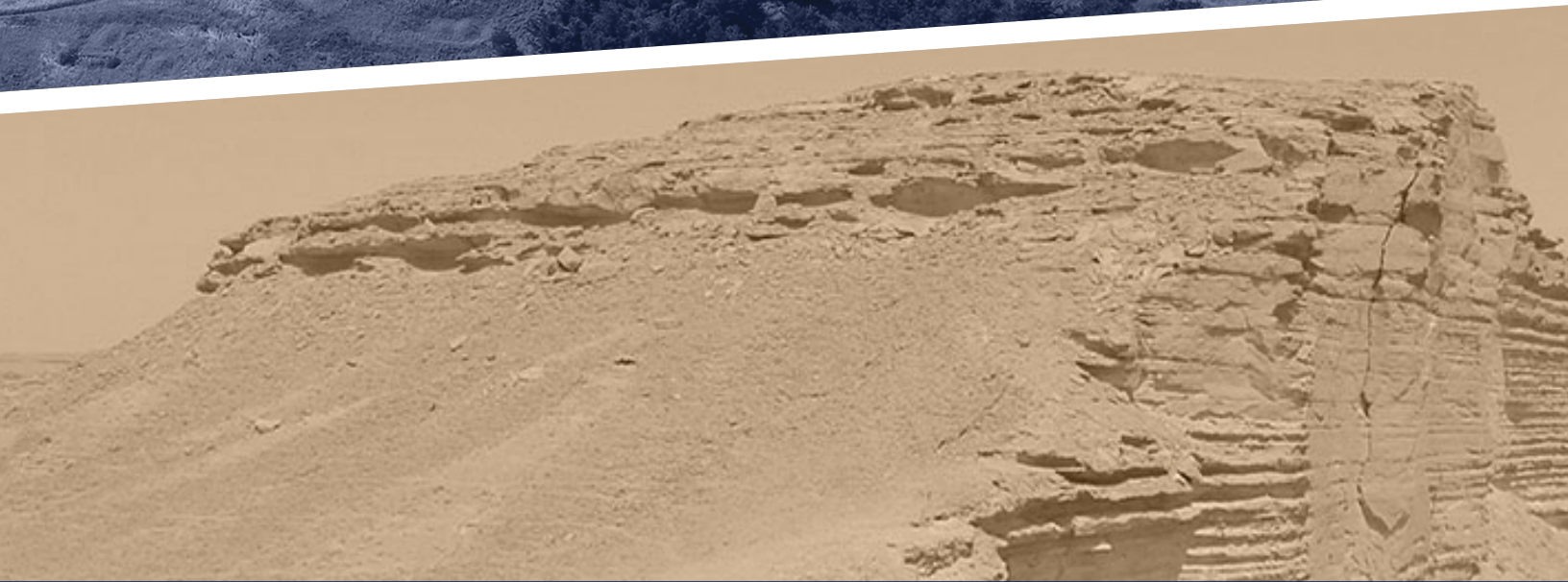
GLOBAL CHANGES

MIT JOINT PROGRAM ON THE SCIENCE & POLICY OF GLOBAL CHANGE

SPRING 2021 NEWSLETTER



MIT JOINT PROGRAM ON THE SCIENCE AND POLICY OF GLOBAL CHANGE

OUR RESEARCH MISSION

Advancing a sustainable, prosperous world through 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.

OUR 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.

IN THIS ISSUE:

SAVE THE DATE: XLIV GLOBAL CHANGE FORUM

Global Net Zero Emissions Goals

Oct 27–29, 2021 • Cambridge, MA & Online

More information

Attendance is by invitation only.

SPRING 2021 GLOBAL CHANGES

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The climate is moving to greater and greater extremes — acting now can reduce risks


Ronald Prinn

The physical risks of climate change are not just looming in the future but have already become very evident today. Projections of rising global temperatures in a just-released World Meteorological Organization report, along with observations from recent years, underscore that the climate system is not static but moving to greater and greater extremes. The 10 warmest years recorded with thermometers since records began in 1880 (140 years ago) all occur within the last 16 years. These changing global warming statistics patterns are reflected at the regional level, as evidenced by the total domination of dark red "record warm" pixels over dark blue "record cold" pixels (none) in NOAA's regional temperature map for 2020.

Moreover, the year 2020 (a La Niña year) has approximately tied 2016 (an El Niño year) as the record warmest year. Why is that a surprise? Because La Niña years are generally cooler and El Niño years are generally warmer than usual. La Niña and El Niño conditions, along with volcanos (cooling) and other natural variations, add year-to-year variability to the otherwise monotonic global warming driven by greenhouse gases and other air pollutants.

Along with surface-level warming, the Earth's atmosphere is becoming more humid, and climate extremes more intense and frequent. Arctic summer sea ice is disappearing more quickly; the Greenland and Antarctic ice sheets are receding faster; tropical cyclones are intensifying and moving more slowly, creating larger storm surges and precipitation events and more severe flooding; and droughts, extreme heat events and wildfires are intensifying. These trends, on scales from local to global, are now impacting — and in coming decades likely to further impact — vulnerable infrastructure, supply chains and human health, and to induce widespread famine and migration.

There is now substantial evidence that achieving the world's aggressive, long-term goal of keeping the global average surface temperature increase well below 2 degrees Celsius from its preindustrial level will dramatically reduce the physical risks posed by climate change. While the long-term goals of the Paris Agreement suggest that world leaders have taken these physical risks seriously, the near-term targets in the accord are largely not on track to meet those long-term goals without a substantial change in direction starting now.

At the same time, efforts to move the world toward net-zero emissions in alignment with the 2 degrees Celsius goal come with major new local-to-global "transition" risks and accompanying challenges that must be met. This transition involves shifts on political, social, technological and economic fronts, and presents new challenges for financing and economies, from stranded fossil-fuel assets to stranded workers needing retraining. We will need to strike the optimal balance between the risk of over-investing in the near term in today's green technologies that will ultimately be superseded, versus the risk of under-investing in these technologies and subsequently needing to rapidly reduce greenhouse gas emissions with the resultant economic shocks.

Lowering these transition risks toward net-zero-emissions economies will involve integration of both physical and transitional components, a process that requires new and improved models and frameworks. The goal is to empower decision-makers in government and industry to lower the transition risks as an

integral companion to mitigation strategies. Financial institutions and regulators will also need to get involved. Finally, we will need to invest more and more in adaptation along with mitigation to lower overall climate risks.

To frame future studies of physical and transition risks, MIT's just-released 2021 Global Change Outlook provides probabilistic climate and socio-economic projections obtained using updated probability distributions for key parameters in both the human- and Earth-system components of our Integrated Global System Modeling (IGSM) framework.

These projections provide insight into the probability of outcomes of interest, including emissions, concentrations, temperature, precipitation, GDP and energy. The 2021 Outlook also presents prospects for achieving the Paris Agreement's short-term targets (as defined by Nationally Determined Contributions, or NDCs) and long-term goals of keeping the increase in the average global temperature below 2 degrees Celsius or even 1.5 degrees.

Finally, the solutions to these challenges need to be affordable and equitable for all people and all nations. The poorest countries are the most vulnerable and the least responsible for climate change. And the COVID-19 pandemic superimposed on climate change has exposed the compounding effects of multiple stressors on these same vulnerable populations.

—Ronald Prinn, Director

Reproduced here in its entirety, this perspective was published in the May 30 edition of The Hill.

MIT DEPARTMENT ACRONYMS

Due to space considerations, MIT departments, labs and centers referenced here are referred to by their acronyms.

CEEPR	Center for Energy and Environmental Policy Research
EAPS	Earth, Atmospheric and Planetary Sciences
IDSS	Institute for Data, Systems and Society
ILP	Industrial Liason Program
MITEI	MIT Energy Initiative

MIT Joint Program News Releases:
Latest research developments and their implications

MIT Joint Program in the Media:
Latest coverage of our research

The following summaries are listed by primary research focus area, but may span multiple research focus areas. For more information on Joint Program research, please visit our website at globalchange.mit.edu.

Earth Systems

Changes and risks to interconnected land, ocean, atmosphere and biosphere systems

Revamped MIT Climate Portal aims to inform and empower the public

Website features accessible "Explainers" by MIT Joint Program researchers and other MIT climate experts

Stepping up its ongoing efforts to inform and empower the public on the issue of climate change, MIT announced a dramatic overhaul of the MIT Climate Portal, climate.mit.edu, which provides timely, science-based information about the causes and consequences of climate change—and what can be done to address it. (Source: Environmental Solutions Initiative)

Climate change: Where we are, where we're headed, what we can do

MIT Joint Program faculty affiliate Noelle Selin shares scientific perspective in Civic Series webinar

IDSS/EAPS Professor Selin describes how much the climate has changed since pre-industrial times; its likely trajectory in the coming decades under current emissions-reduction policies; and what nations, states and individuals can do to slow it down and avoid the worst impacts of climate change.

Reductions in CFC-11 emissions put ozone recovery back on track

Scientists observe reduction in emissions of banned ozone-depleting chemical after unexpected spike

Researchers traced a substantial fraction of the global emission reductions to the very same regions of eastern China where they had previously reported the original spike. The results are consistent with evidence that the country has taken successful actions to stamp out illegal production of this ozone-depleting chemical.

Study predicts the oceans will start emitting ozone-depleting CFCs

As atmospheric concentrations of CFC-11 drop, the global ocean should become a source of the chemical by the middle of next century (Coverage: Scientific American)

Researchers report that the global ocean will reverse its longtime role as a sink for the potent ozone-depleting chemical. They project that by the year 2075, the oceans will emit more CFC-11 back into the atmosphere than they absorb, emitting detectable amounts of the chemical by 2130. Further, with increasing climate change, this shift will occur 10 years earlier.

PODCAST **Is it too late to prevent climate change? (*TILclimate*)**
What it will take to achieve long-term climate goals

An aerial view of the Gosan Observatory, including the AGAGE station in Gosan, South Korea (lower left), which takes hourly measurements of more than 50 trace gases, including CFC-11.

Managed Resources

Changes and risks to managed agriculture, water, land and energy systems

AGU Fall Meeting goes online for 2020

Joint Program researchers to share findings on the state of global change

Fourteen core members or affiliates of the Joint Program were co-authors of oral and poster presentations, and conveners of conference sessions at the 2020 AGU Fall Meeting. Topics included modeling the ocean carbon cycle, assessing risks across multiple Earth systems and economic sectors, enabling proactive adaptation to global change, designing effective climate and air pollution policies, and quantifying uncertainty in global change projections.

Photo: AGU Fall Meeting Central Exhibit Hall

MANAGED RESOURCES (CONT'D)

Breakthrough study confirms global food production poses an increasing climate threat

Nature paper co-authors include Joint Program Director Ronald Prinn and Collaborator Hanqin Tian (lead) (Coverage: The Guardian, The Conversation)

Study finds that rising anthropogenic nitrous oxide emissions are jeopardizing climate goals and the Paris Agreement. The significant use of nitrogen fertilizers in the production of food worldwide is increasing concentrations of nitrous oxide in the atmosphere—a greenhouse gas 300 times more potent than carbon dioxide—which remains in the atmosphere longer than a human lifetime. (Source: Auburn University)

Cleaning up electricity (*The American Prospect*)
A federal energy efficiency and clean electricity standard is doable, but getting one through Congress won't be easy

Infrastructure & Investment

Physical and transition risk; adaptation and resilience to climate change and extreme events

Global changes: Physical and transition risks

XLIII (43rd) MIT Global Change Forum highlights opportunities for science-based decision-making

The Forum was presented in four two-hour Zoom sessions in late October 2020: Scenarios: Physical & Transition Risks, Regional Hotspots for Climate Risks, Sustainable Development Goals, and Urban Transitions. Presentations and discussions explored efforts to quantify physical and transition risk and how such assessments could be used to inform decision-making.

Visualizing a climate-resilient MIT

New climate resiliency dashboard helps reduce uncertainty of current and future flood risks in Cambridge

The dashboard is an essential planning tool for ongoing work to build a climate-resilient MIT, one that fulfills its mission in the face of impacts of climate change. It's also a tool that highlights the importance of collaboration in devising sustainability solutions. (Source: MIT Office of Sustainability)

The XLIII (43rd) MIT Global Change Forum was held on Zoom.

COMMENTARY **Multiple extreme climate events can combine to produce catastrophic damages *(Yale Climate Connections)***
Concurrent extreme climate events can amount to a challenging 'two-fer' or even a 'three-fer' in terms of adverse impacts

Energy Transition

National and global projections of the future energy mix; prospects for different sectors and technologies

Powering through the coming energy transition

Carbon capture and storage key to achieving climate goals

A new study assessed the potential of CCS and its competitors in mitigating carbon emissions in the power sector under a policy scenario aligned with the 2°C Paris goal. The researchers found that under this scenario and the model's baseline estimates of technology costs and performance, CCS will likely be incorporated in nearly 40 percent of global electricity production by 2100.

The Roads to Carbon Neutral: Episode 1 - The Climate Issue
Joint Program Co-Director Emeritus John Reilly featured in CNBC/Total advertorial

COVID-19 as a catalyst for change in the move towards net zero emissions *(Harvard Advanced Leadership Initiative Social Impact Review)*
An interview with Dr. John M. Reilly

Navigating the energy transition

ILP-MIT Joint Program webinar explores climate-related physical and transition risks

The November 2020 webinar focused on understanding and managing "physical risks" related to damage from climate events such as floods, droughts, wind and extreme temperatures, and "transition risks" that arise from shifts in the political, technological, social and economic landscape that are likely to occur during the transition to a low-carbon economy.

Negative emissions, positive economy

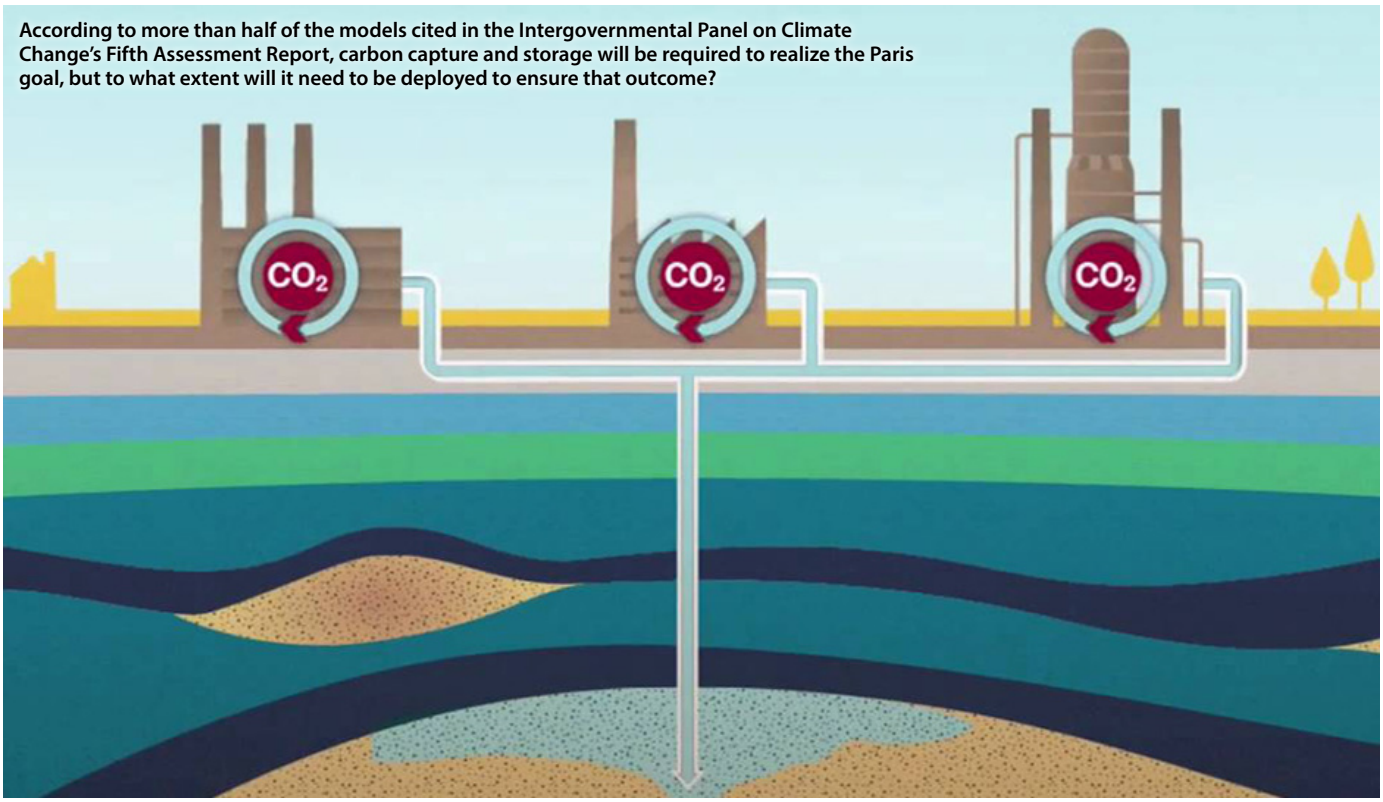
How bioenergy with carbon capture and storage (BECCS) could help stabilize the climate without breaking the bank

Researchers find that while it's economically feasible to implement emissions-reduction policies aligned with the 2°C and 1.5°C Paris goals without relying on BECCS, large-scale deployment of the technology in the second half of the century significantly lowers the overall implementation costs. Moreover, the inclusion of BECCS in these policies prevents widespread economic damages.

Collaborators in climate action

Symposium highlights ambitious goals of MIT–industry research targeting technologies to reduce greenhouse gas emissions

MIT Joint Program/MITEI research scientist Jennifer Morris provided policy scenario projections for the Mobility of the Future Study. This work proved useful not just to ExxonMobil, but to MIT as well. The goal is to make such research widely available to policymakers, industry and other stakeholders to inform decision-making that can drive decarbonization. (Source: MIT Energy Initiative)



According to more than half of the models cited in the Intergovernmental Panel on Climate Change's Fifth Assessment Report, carbon capture and storage will be required to realize the Paris goal, but to what extent will it need to be deployed to ensure that outcome?

Policy Scenarios

Environmental and economic change under different climate, air pollution, and economic policies

Mercury Stories: Understanding Sustainability through a Volatile Element

MIT EAPS/IDSS Assoc. Prof. and Joint Program faculty affiliate Noelle Selin co-authors new book

The book explores how people have made beneficial use of mercury, how they have been harmed by its toxic properties and how they have tried to protect themselves and the environment from its damaging effects. Taking a systems approach, the authors develop and apply an analytical framework that can inform other efforts to evaluate and promote sustainability. (Source: MIT Press)

POLICY SCENARIOS (CONT'D)

Climate AI: How artificial intelligence can power your climate action strategy

Former Joint Program Co-Director John Reilly quoted in new report from Capgemini Research Institute

Report finds that in the past two years, AI-enabled use cases have already helped organizations reduce greenhouse gas emissions by 13% and improve power efficiency by 11%, and estimates that by 2030, AI-enabled use cases have the potential to help organizations fulfill 11–45% of the "Economic Emission Intensity" targets of the Paris Agreement.

How will Covid-19 ultimately impact climate change?

Study probes pandemic's long-term effects on the global effort to reduce greenhouse gas emissions

A Joint Program study shows that reduced economic activity resulting from Covid-19 lowers the cost of meeting Paris Agreement emissions targets, making such commitments more politically palatable. Moreover, fiscal stimulus measures to accelerate economic recovery present an opportunity for major investments in emissions-reduction efforts.

Mitigation of CO_2 emissions from international shipping through national allocation

Allocating CO_2 to the "owner country" best meets equity and effectiveness criteria

Researchers explore how mitigation of carbon dioxide emissions from international shipping could be mitigated by allocating these emissions to countries based on the location of a shipping actor. Assessing five potential allocation options, they find that a clear majority of CO_2 emissions could be distributed to ten countries under each of the options examined. (Source: Boston University)

COMMENTARY **Rejoining the global fight against climate change: In the U.S.'s national interest *(Yale Climate Connections)***
Restoring its international standing on climate leadership is critical to the country's national interests and global stability

COMMENTARY **Inaction on the climate threat is NOT an option *(Yale Climate Connections)***
Lessons from coronavirus inform and enhance our understanding of needed next steps on climate change crisis

Bringing down mercury *(MIT Spectrum)*
Noelle Selin explores toxin's history, works to change policy

COMMENTARY **Early next step: Add risk management to National Climate Assessment *(Yale Climate Connections)***
Adding the essential but missing risk management considerations to the next national climate assessment is an important step for the incoming Biden administration

COMMENTARY **There's a simple way to green the economy – and it involves cash prizes for all *(The Guardian)***
The 'carbon dividend' is so elegant that it seems too good to be true. Governments should make it a post-pandemic priority

COMMENTARY **Biden Channels FDR on STEM Policy *(Scientific American)***
The president's letter to his new science advisor emphasizes the crucial role science plays in our society—much as Roosevelt did in a similar missive in 1944

Did the pandemic show us that we can cut carbon emissions? Sort of. *(NBC News)*
If the pandemic revealed what could be considered low-hanging fruit in the climate fight, it also highlighted the sheer scope of the problem

In Biden climate show, watch for cajoling, conflict, pathos *(Associated Press)*
Joint Program Founding Co-Director Emeritus Henry Jacoby comments (Related: AP)

Assuming a return to pre-pandemic levels of employment by 2035, a Joint Program study finds that Covid-19 produces a steep, 8.2 percent reduction in global GDP in 2020, but only a 2 percent reduction in 2035. Seen here: a Covid-19 center near Washington, D.C.

Regional Analysis

Science and policy studies at subnational, national and multinational levels

Saudi Arabia faces increased heat, humidity, precipitation extremes by mid-century

High-resolution climate projections could enable a robust adaptation and resilience response

Researchers projected increasing temperatures by mid-century across the country, including five strategic locations in both August and November, and a rising August heat index that threatens regional habitability in Jeddah due to an increasing frequency of extreme heat index days.

Researchers from the MIT Joint Program and the King Abdulaziz City for Science and Technology's Center for Complex Engineering Systems used a high-resolution, regional climate modeling approach to generate mid-21st century (2041–2050) projections for Saudi Arabia under a high-emissions, high-climate-impact scenario.

Water and environment security for socioeconomic transformation in Uganda

Joint Program research scientist Kenneth Strzepek delivers keynote presentation at Uganda Water & Environment Week 2021 conference

Strzepek emphasized that government must play a key role in providing physical and institutional infrastructure to enable sustainable and inclusive economic growth. To provide a framework and tools to advance that objective, he recommended that Uganda develop an integrated water and environmental investment plan.

Can U.S. states afford to meet net-zero emissions targets by 2050?

In the Northeast, Canadian hydropower could make it so

Compared to a reference scenario aligned with achieving mid-century regional emissions goals, researchers estimate that by 2050, electricity imports enabled under three different hydropower transmission expansion scenarios save the New York state economy 38–40 cents per kilowatt hour (kWh) and the New England economy 30–33 cents per kWh.

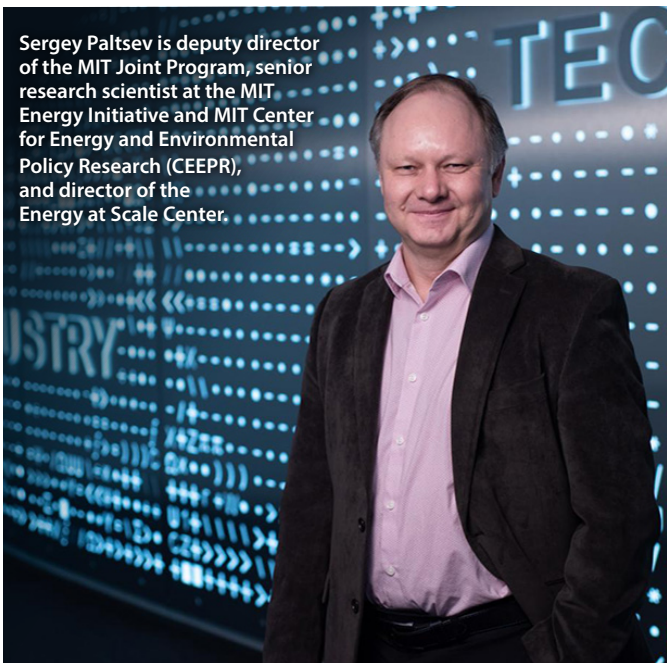
Modeling Systems

Our state-of-the-art models and analytical methods project global and regional changes and potential risks under different policy scenarios

Assessing and managing risks amid global and regional change

Webinar presentation highlights Joint Program's contribution to MIT's sustainability research portfolio

A key contributor to MIT's sustainability research portfolio is the Joint Program, which since 1991 has pursued research enabling decision-makers to address environmental protection, economic viability and social equity. To that end, the Program's researchers use leading-edge computer models to perform integrated assessments of Earth and human systems under different scenarios.



Sergey Paltsev is deputy director of the MIT Joint Program, senior research scientist at the MIT Energy Initiative and MIT Center for Energy and Environmental Policy Research (CEEPR), and director of the Energy at Scale Center.

Improving models for solar climate intervention research (*Eos*)

Modern climate models were designed to simulate natural systems and changes mainly due to atmospheric carbon dioxide, rather than to predict effects of deliberate climate interventions

New Research Projects

Identifying strategic pathways toward sustainability: An integrated approach to address climate and human health

Sponsor: Biogen

Leaders: Noelle Selin, C. Adam Schlosser

Duration: 3 years

Existing climate targets do not consider or identify the impact of successful pathways that also achieve an environment that supports and protects human health. This project seeks to develop "headline indicators" of human well-being that can assess the relative impact on health of global progress towards global temperature targets. It will illustrate these targets with analysis of the health impacts of air pollution, a major cause of death and disease globally that is fundamentally linked to the climate challenge through fossil fuel use. Project researchers aim to develop and establish novel climate-health targets; determine the most effective solutions to achieve these targets; and quantify risks and consequences of these global solutions. They envision two key outcomes: to build capacity to bring research to bear on policy-decision-making, and to enhance the scientific basis for action to address future sustainability challenges with a focus on human well-being.

Uncertainty characterization and scenario discovery in the Global Change Intersectoral Modeling System (GCIMS)

Sponsor: DOE

Leader: Jennifer Morris

Duration: 4 years

This project focuses on the role of influences, responses and feedbacks in the coupled human–Earth system. Specifically: (1) how compounding human and environmental influences affect the coevolution of energy, water, land, climate and socioeconomic systems; (2) how regional teleconnections via trade create, amplify or attenuate the effect of these influences; (3) how human responses to short-term influences affect the long-term dynamics of these systems through investments in storage technologies; and (4) how the response of the human–Earth system to influences creates feedbacks that have the potential to alter the original influences. Scientific advances emerging from this work may include improved emulation of human and environmental influences; advances in understanding how demand, trade, storage and other responses interact across energy, water and land systems; and identification of new potential feedbacks between natural systems and human activities.

Assessing future socioeconomics and climate modeling

Sponsor: EPRI

Leader: Jennifer Morris

Duration: 6 months

Global socioeconomic and greenhouse gas (GHG) emissions projections and consideration of uncertainty are needed for climate policy applications, and global emissions pathways are being prescribed to address climate change. However, most projections to date are without probabilistic interpretation or coherency across variables and scales. In addition, climate modeling and resulting projections are a key factor in differences in estimating the social cost of carbon (SCC), as well as future potential overall climate damages and climate management strategies. However, existing SCC climate modeling is problematic and there is need for formal evaluation and potential improvements. The objectives of this project are to (a) evaluate future socioeconomic and greenhouse gas emissions uncertainty, in particular, uncertainty regarding socioeconomic structure (region, sector, demand, energy, technology); and (b) contribute to a multi-model evaluation and comparison of climate model behavior and climate change response uncertainty.

Impact of changing sea-ice regime on Arctic Ocean biology

Sponsor: NASA / JPL

Leader: Stephanie Dutkiewicz

Duration: 3 years

This project's researchers will provide expertise in model enhancements to MITgcm and DARWIN code base in order to improve the parameterization of sea ice and coastal biogeochemical processes and the impact of these processes on ocean color. In particular, they will advise in the implementation of parameterizations of melt ponds, light transmission through ice and ponds, under-ice blooms, representation of river sediments, and radiative transfer schemes. They will also advise in the analysis of observations and model-data comparisons, and contribute to project publications.

Assessment of CCS in a climate mitigation portfolio: Focus on negative emissions technologies and hydrogen

Sponsor: ExxonMobil

Leaders: Sergey Paltsev and Howard Herzog

Duration: 3 years

This project focuses on negative emissions technologies (bioenergy with carbon capture and storage, direct air capture, etc.) and hydrogen in a portfolio of mitigation options, including strategies to advance the carbon capture and storage (CCS) option. Researchers will update/improve the accuracy of models for the deployment of negative emissions technologies and hydrogen and other competing/complementing options based on recent experience, literature and data; and use the MIT EPPA model to examine different longterm scenarios to estimate the importance of factors influencing advanced technology deployment. Options for decarbonization in power generation, industrial, transportation and residential sectors will be assessed.

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p 5: © Carbon Capture and Storage Association

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p 7(a): © Angus Hamilton Haywood/Flickr

p 7(b): © MIT/ILP

Cover:
(a) see p 6
(b) see p 3(a)
(c) see p 7(a)

Peer-Reviewed Studies

Integrated assessment model diagnostics: Key indicators and model evolution (*Environ Res Lett*)

Mitigation of CO_2 emissions from international shipping through national allocation (*Environ Res Lett*)

The role of cross-border electricity trade in transition to a low-carbon economy in the Northeastern U.S. (*Energy Policy*)

On the effects of the ocean on atmospheric CFC-11 lifetimes and emissions (*PNAS*)

A decline in emissions of CFC-11 and related chemicals from eastern China (*Nature*)

Spatial and sectoral benefit distribution in water-energy system design (*Appl Energy*)

Climate change impacts and costs to U.S. electricity transmission and distribution infrastructure (*Energy*)

Switching on auxiliary devices in vehicular fuel efficiency tests can help cut CO_2 emissions by millions of tons (*One Earth*)

Methyl Chloroform continues to constrain the hydroxyl (OH) variability in the troposphere (*JGR Atmos*)

The increasing atmospheric burden of the greenhouse gas sulfur hexafluoride (SF_6) *(Atmos Chem Phys*)

The global methane budget 2000–2017 (*Earth Syst Sci Data*)

Exploring biogeochemical and ecological redundancy in phytoplankton communities in the global ocean (*Global Change Biol*)

The Covid-19 effect on the Paris Agreement (*Human & Soc Sci Comm*)

Improving Evaluation of Energy Policies with Multiple Goals: Comparing Ex Ante and Ex Post Approaches (*Environ Sci Technol*)

The ECCO-Darwin Data-Assimilative Global Ocean Biogeochemistry Model: Estimates of Seasonal to Multidecadal Surface Ocean pCO_2 and Air-Sea CO_2 Flux (*J Adv Model Earth Sys*)

The Importance of the Phytoplankton 'Middle Class' to Ocean Net Community Production (*Global Biogeochem Cycles*)

Utility-scale portable energy storage systems (*Joule*)

Emulation of Community Land Model Version 5 (CLM5) to quantify sensitivity of soil moisture to uncertain parameters *(J Hydrometeorol*)

Integrated climate-change assessment scenarios and carbon dioxide removal (*One Earth*)

Use of natural gas and oil as a source of feedstocks (*Energy Econ*)

Mid-century changes in the mean and extreme climate in the Kingdom of Saudi Arabia and implications for water harvesting and climate adaptation (*Atmosphere*)

Joint Program Reports

344. Future energy: In search of a scenario reflecting current and future pressures and trends

345. The economics of bioenergy with carbon capture and storage (BECCS) deployment in a 1.5°C or 2°C world

346. Renewable energy transition in the Turkish power sector: A techno-economic analysis with a high-resolution power expansion model, TR-Power

347. Representing socio-economic uncertainty in human system models

348. Changing the Global Energy System: Temperature Implications of the Different Storylines in the 2021 Shell Energy Transformation Scenarios

349. A consistent framework for uncertainty in coupled human-Earth system models

350. Hydroclimatic analysis of climate change risks to global corporate assets in support of deep-dive valuation

351. Meeting potential new U.S. climate goals

352. Toward resilient energy infrastructure: Understanding the effects of changes in the climate mean and extreme events in the Northeastern United States

353. Predictability of U.S. regional extreme precipitation occurrence based on large-scale meteorological patterns (LSMPs)

Milestones

Joint Program Deputy Director **Sergey Paltsev** and Research Scientist **Angelo Gurgel** are part of a team that received an **MIT Imperial Seed Fund** Award for their project "Nature-Based Solutions for Accelerating Climate Action." The Fund promotes early-stage collaboration between faculty and researchers at MIT and Imperial College London focused on the themes of "climate solutions" and/or "transitioning to zero pollution."

MIT EAPS Professor **Susan Solomon** received the 2021 National Academy of Sciences Award for Chemistry in Service to Society for contributions to understanding and communicating the causes of ozone depletion and climate change.

Solomon also received the 2020–2021 James R. Killian, Jr. Faculty Achievement Award at MIT, and delivered a one-hour Killian Lecture in which she touched on her path to MIT, her time in Antarctica, her work on ozone depletion, and her insights on the state of climate policy.

MIT JOINT PROGRAM ON THE SCIENCE AND POLICY of GLOBAL CHANGE

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