GLOBAL CHANGES

MIT JOINT PROGRAM ON THE SCIENCE & POLICY OF GLOBAL CHANGE

SPRING 2024 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.

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SAVE THE DATE:
XLVII (47TH) GLOBAL CHANGE FORUM

Mar. 27–28, 2025 • Sponsor Meeting on Mar. 26

MIT Campus

Attendance is by invitation only.

The reporting period for this issue is Nov 2023 - Apr 2024.

MIT JOINT PROGRAM ON THE SCIENCE AND POLICY OF GLOBAL CHANGE

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SPRING 2024 GLOBAL CHANGES

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Predicting and preparing for tipping points in a changing and complex world

News headlines about "tipping points" have proliferated in recent years, particularly in stories about severe and potentially irreversible climate impacts the world may face if human-caused greenhouse gas emissions are not dramatically reduced. But what exactly is a tipping point?

Conventional definitions typically refer to a critical state in any situation, process or system in which an additional minor action can cause a significant, abrupt and/or unstoppable effect or change. The mainstream use of "tipping point" stems from a sociological adoption in the 1960s of the classic physics concept (i.e., a toppling object nudged past its balance point) to characterize the collective sociological behavior and sudden movement of residential populations along racial lines. Since then, the term has been used to describe numerous concepts, cautionary pathways, and abrupt behaviors across economics, natural ecosystems, epidemiology and managed resources, among others. And its use has been expanded to include positive outcomes, as in how little changes and seemingly small actions can lead to big differences and improvements in people's lives.

In the scientific community, the notion of tipping points as cautionary is weaved into concepts of "failures," "breakpoints," "thresholds," "unintended consequences," and "cascading and compounding risks" across multiple systems. All these conceptual applications reflect the growing complexities of our global society, with multiple pressures impinging on numerous and interconnected systems that we rely upon and often require to operate without interruption. This calls for the development of scientific capabilities that can identify potential tipping points and enable decision-makers to take actions to minimize the risks that they pose.

Research challenges and opportunities

The challenges for the scientific community lie in recognizing, understanding and predicting these critical moments; and in providing clear language and information to governments, stakeholders and the general public on how best to prepare for them. The predictive

C. Adam Schlosser – Deputy Director, MIT Joint Program

tools needed to meet these challenges require comprehensive and sufficiently detailed representations of the natural environment, managed resources, social landscapes, economic sectors and built infrastructure, and the interconnections between them. These tools must also represent key dynamics, how local changes can affect change elsewhere; how various changes can collectively lead to abrupt, cascading and/or compounding responses and failures; and what measures can be put in place to avoid risk and improve resiliency, all while ensuring a sustainable, prosperous future.

To date, predictive tools informed by multi-sector dynamics (MSD)—a research perspective and methodology in which natural, managed and built systems are viewed as interconnected contributors to tipping-point responses that cannot be revealed through siloed, single-system assessments—have successfully identified real-world tipping points. Such research has uncovered how the widespread failure of the Texas power grid was a result of compounding effects in supply, distribution, regulation and demand during the record-breaking 2021 cold wave. Other MSD research has demonstrated how encroachment of land use and infrastructure into undisturbed environments degrades the intactness—and eventually causes collapse—of regional biodiversity. Recent MSD-based evidence also suggests that a global "tipping point"

in renewable energy is imminent, with market forces (initially driven by low-carbon/climate targets) causing solar power to become the cheapest form of energy in the coming years, and that similar dynamics will subsequently propel other clean energy technologies (i.e., wind and batteries) in this fashion.

Evidence of these episodic, regional-scale and market-specific occurrences and expectations of tipping points is rising, but key challenges remain. First, consensus has yet to be reached on what, where and when systems would reach the point of any large-scale and/or global collapses, and the extent to which positive tipping points can counteract negative ones. Further, the necessary actions to be taken to reduce or prepare for any such tipping points (local to global) without creating commensurate or more egregious threats have not been comprehensively assessed. Finally, the prioritization of any set of preventative and preparatory actions must also consider sustainability and justice implications.

Real progress on these research challenges will require sweeping advances—not only in modeling, analyzing and predicting with sufficient detail the evolution of multiple, complex, interconnected systems that are natural, managed and built, but also in developing computational and numerical methods that can handle the prolific and inexorable growth in data.

The MIT Joint Program's evolving capabilities

Since the development and inaugural release of the Integrated Global Systems Model (IGSM) framework more than 30 years ago, the MIT Joint Program on the Science and Policy of Global Change has and continues to pioneer MSD research. This began with the IGSM's landmark ability to quantitatively assess the effectiveness of global and national low-carbon policies in achieving climate targets through a rigorous approach that considered plausible responses across both human (energy-economic) and Earth systems. Since then, the IGSM framework has been expanded to explore risks of regional climate changes, energy and power systems, land resources, managed water systems, ecosystems and extreme events. We have also developed our **S**ystem for the **T**riage of **R**isks from **E**nvironmental and **S**ocio-economic **S**tressors (STRESS) platform, an open-science visualization interface to combine, overlay and diagnose landscapes of socio-economic, health and environmental risk and injustice. With the ongoing support of our federal and industrial sponsors—most notably the Department of Energy—we continue to expand our capabilities in critical areas and galvanize engagement with the scientific community.

To showcase and enhance MSD research capabilities developed by the Joint Program and collaborating institutions, we will soon be launching a new webinar series focused on tipping points. The first session will provide literature-based assessment of the scientific research to explore the definition of "tipping points," how and the extent to which the science has evolved under the nomenclature of "tipping points," what are the most promising and perhaps unrealized synergies and collaborations, and how can we align these with key priorities. The webinar series will continue with sessions that focus on key research areas, integrated themes and approaches that include: the natural environment, managed resources, economics, human health and well-being, energy systems, infrastructure and the built environment, equity and justice, the role of scale and resolution, prospects and limits of AI and machine learning, compounding tipping points, and advances in multi-system assessments.

—C. Adam Schlosser, Deputy Director

MIT Joint Program Principal Research Scientist Jennifer Morris contributed to this Perspective.

The following news and media coverage summaries are listed along with the Research Focus Area(s) that they represent. To view all of our news releases and media coverage, and detailed descriptions of our research focus areas and tools, please visit our website at globalchange.mit.edu.

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

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

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

Energy Transition
National & global projections of the future energy mix; prospects for different sectors & technologies

Policy Scenarios
Environmental & economic change under different climate, air pollution, & economic policies

Regional Analysis
Science and policy studies at subnational, national and multinational levels

Multi-Sector Dynamics
Potential tipping points and transition states of Earth and human systems

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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

Based on a rigorous, integrated analysis of population and economic growth, technological change, Paris Agreement emissions-reduction pledges, geopolitical tensions and other factors, this report presents the MIT Joint Program's 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.

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Atmospheric observations in China show rise in emissions of sulfur hexafluoride (SF_6), a potent greenhouse gas

Global warming potential of SF_6 is more than 24,000 times that of carbon dioxide

This study found that SF_6 emissions in China almost doubled from 2.6 gigagrams (Gg) per year in 2011, when they accounted for 34% of global SF_6 emissions, to 5.1 Gg per year in 2021, when they accounted for 57% of global total SF_6 emissions. This 10-year increase was larger than the global total SF_6 emissions rise, highlighting the importance of lowering SF_6 emissions from China in the future.

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Pathways to more resilient power systems

Study highlights factors that could reduce climate risk

MIT Joint Program researchers evaluate how projected future climate change would impact annual power production and demand in the central U.S. under a range of scenarios of how the power sector might evolve through midcentury. For each scenario, subregion, and power-system component, they determine a "potential supply gap" due to these climate-driven effects.

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Power sector impacts of the Inflation Reduction Act

IRA helps to bring projected U.S. power sector and economy-wide emissions closer to near-term climate targets (EPRI)

A new 11-model comparison examines the power sector impacts of the Inflation Reduction Act of 2022 (IRA). Although the IRA helps to bring projected U.S. power sector and economy-wide emissions closer to near-term climate targets, no models indicate that these targets will be met with IRA alone, which suggests that additional policies, incentives, and private sector actions are needed.

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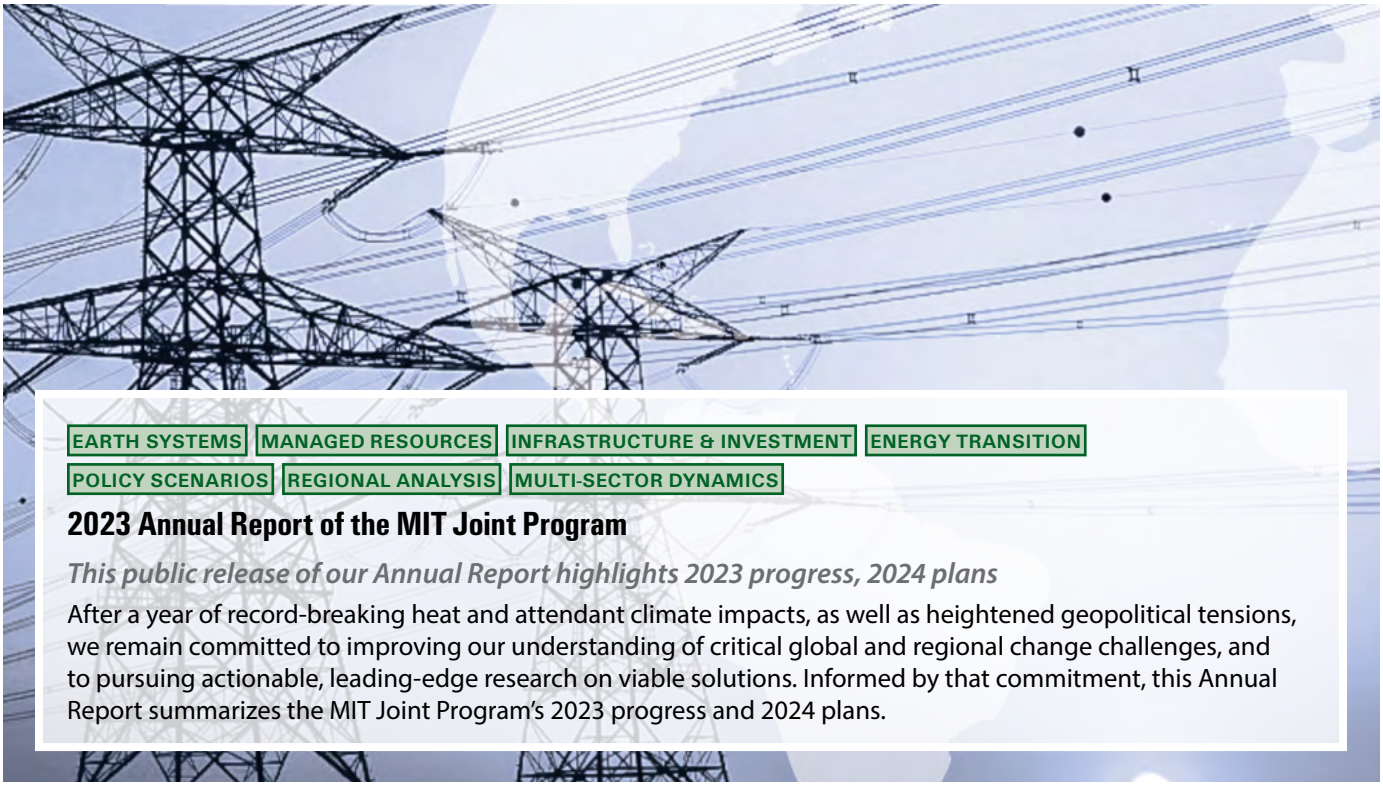
Study: Global deforestation leads to more mercury pollution

Scientists quantify a previously overlooked driver of human-related mercury emissions (MIT News) (Coverage: WFXT(Fox))

An MIT study finds that about 10% of human-made mercury emissions into the atmosphere each year result from global deforestation. The world's vegetation, from the Amazon rainforest to the savannahs of sub-Saharan Africa, acts as a sink that removes the toxic pollutant from the air. But if the current rate of deforestation remains unchanged or accelerates, net mercury emissions will likely keep increasing.



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2023 Annual Report of the MIT Joint Program

This public release of our Annual Report highlights 2023 progress, 2024 plans

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. Informed by that commitment, this Annual Report summarizes the MIT Joint Program's 2023 progress and 2024 plans.

MANAGED RESOURCES | REGIONAL ANALYSIS

High school student co-authors MIT Joint Program journal article on recreation-use value of U.S. natural lands

Her research nets first place award in Behavioral & Social Sciences category at Regeneron Westchester Science & Engineering Fair

Appearing in *Environmental Challenges,* this study shows that New England natural lands provide $88 billion per year in recreation-use value to U.S. citizens who partake in wildlife-related activities. Compared with the estimated cumulative federal and state contributions to land conservation in New England between 2004 and 2014 (< $1 billion), that $88 billion is an impressive return on investment.

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Healey-Driscoll Administration launches Climate Science Advisory Panel

New advisory panel to provide essential guidance on current climate data best practices and needs (MA Executive Office of Energy and Environmental Affairs)

The Healey-Driscoll Administration recently launched a Climate Science Advisory Panel to provide expertise on statewide climate science and future projections used to inform state and local climate adaptation planning and projects. The Panel is comprised of experts within Massachusetts and across the region, including MIT Joint Program Deputy Director C. Adam Schlosser.

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Reflecting on COP28 — and humanity's progress toward meeting global climate goals

MIT delegates share observations and insights from the largest-ever UN climate conference (MIT Office of the Vice President for Research)

An MIT delegation that included MIT Joint Program Deputy Director Sergey Paltsev was in Dubai to observe the negotiations, speak on panels, network, and conduct research.

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MIT Joint Program at COP28

Knowledge to action: Co-developing local solutions to the climate crisis

MIT Joint Program Deputy Director Sergey Paltsev delivered a presentation as part of a panel for "Knowledge to Action: Co-developing Local Solutions to the Climate Crisis," an official COP28 side event. Paltsev's introductory statement focused on Joint Program expertise and tools that promote equitable climate solutions at local, regional and global levels.

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

Key takeaways from the XLVI (46th) MIT Global Change Forum

At the XLVI (46th) MIT Global Change Forum on March 28-29, 2024, more than 100 attendees from industry, academia, government and NGOs gathered at the Samberg Conference Center on the MIT campus to explore climate change trends, physical and economic climate impacts, and policy and communications strategies to accelerate climate action as global temperatures continue to soar.

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MIT Joint Program at CERAWeek

Deputy Director Sergey Paltsev speaks on the 1.5°C climate target and flying with hydrogen (Coverage: Houston Chronicle)

One of four speakers at a March 19 session entitled "Is 1.5°C goal still relevant?" at CERAWeek, the world's premier energy conference, Paltsev urged decision-makers to simply focus on taking accelerated action to reduce greenhouse gas emissions. In a separate session on the use of hydrogen in aviation, he discussed the role of sustainable aviation fuels (SAF) in decarbonizing the aviation industry.

INFRASTRUCTURE & INVESTMENT | ENERGY TRANSITION

Building momentum and advancing ideas toward scalable solutions to climate change

MIT Joint Program Deputy Director Sergey Paltsev describes climate risk drivers and how MIT researchers are forecasting their impacts on businesses (MIT Climate & Sustainability Consortium)

In a panel on the physical and transition risks of climate change, Paltsev described specific risk drivers and how MIT researchers are forecasting their impacts on businesses. "There is a significant gap between the way the economy currently assesses the risk of businesses' operations and the risk of the same operations in a world that is heading towards net-zero," he said.

INFRASTRUCTURE & INVESTMENT | ENERGY TRANSITION | POLICY SCENARIOS

Amundi and the MIT Joint Program announce joint research paper

Paper connects long-term climate scenarios with corresponding financial impacts at the company level (Amundi)

A joint research paper by Amundi and the MIT Joint Program explores climate stress testing and net-zero valuation. Serving as a case study for selected energy-intensive companies, the paper combines Amundi's expertise in asset management and financial valuations, and the MIT Joint Program's expertise in climate and energy-transition scenarios.

MANAGED RESOURCES | ENERGY TRANSITION | POLICY SCENARIOS

Explained: Carbon credits

Can carbon trading systems reduce global emissions, or are they little more than greenwashing? Clear, enforceable standards may make the difference. (MIT News)

MIT Joint Program Deputy Director Sergey Paltsev observes that while such nature-based systems for countering carbon emissions can be a key component of addressing climate change, especially in very difficult-to-decarbonize industries such as aviation, carbon credits for such programs "shouldn't be a replacement for our efforts at emissions reduction."

MIT Joint Program in the Media

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COMMENTARY: 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)

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COMMENTARY: 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)

EARTH SYSTEMS | POLICY SCENARIOS

COMMENTARY: We don't need to repeat the Trump experiment

The climate consequences could be serious, MIT Joint Program Founding Co-Director Emeritus Henry Jacoby and co-authors warn (The Hill)

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PODCAST: Do carbon offsets help with airplane emissions?

MIT Joint Program Research Scientist Angelo Gurgel shares his expertise as a guest on the Anti-Dread Climate Podcast (NPR/KCRW)

MANAGED RESOURCES | ENERGY TRANSITION

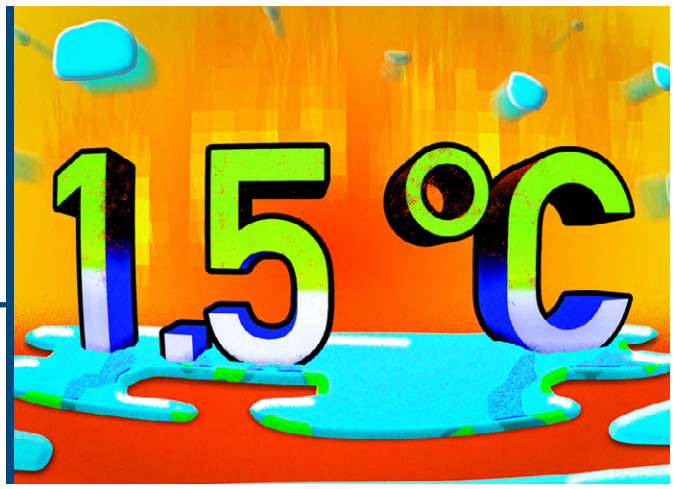
Why hydrogen is losing the race to power cleaner cars

Batteries are dominating zero-emissions vehicles, and the fuel has better uses elsewhere (MIT Technology Review)

MANAGED RESOURCES | ENERGY TRANSITION

EPA says it's 'looking into' study that found electric cars are MORE toxic than gas-powered vehicles

Study suggested EVs expel more particulate matter through their tires and brakes than modern gas-powered vehicles due to added weight from batteries (Daily Mail)



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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)

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Electric Vehicles Contribute Fewer Emissions Than Gasoline-Powered Cars Over Their Lifetimes

EV's higher manufacturing emissions are more than offset by their lower operational emissions, says MIT Joint Program Deputy Director Sergey Paltsev (FactCheck.org)

MANAGED RESOURCES
ENERGY TRANSITION REGIONAL ANALYSIS

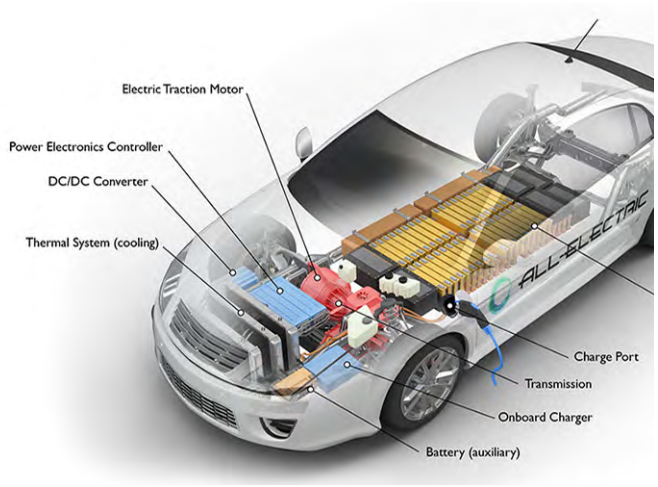
"Sustainable aviation fuel is going to be the main component to decarbonize this sector"

So said MIT Joint Program Deputy Director Sergey Paltsev in a presentation at the April 10-11 Wings of Change Americas conference in Santiago, Chile (Litoral Press, Spanish)

MANAGED RESOURCES INFRASTRUCTURE & INVESTMENT
ENERGY TRANSITION

What will it take to replace gas-powered vehicles with EVs?

We spoke to leading experts across the country to examine the pros — and potential cons — of the coming EV revolution (Progressive)



EARTH SYSTEMS POLICY SCENARIOS

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)

EARTH SYSTEMS MANAGED RESOURCES ENERGY TRANSITION

ASK MIT CLIMATE: How should we measure the CO_2 emissions from biofuels and bioenergy?

To know if bioenergy is truly a low-carbon resource, we must count emissions from growing, transporting, and processing the associated crops, check whether those crops were replanted, and add in any emissions from creating farmland to grow more of them. (MIT Climate Portal)

MANAGED RESOURCES ENERGY TRANSITION
POLICY SCENARIOS REGIONAL ANALYSIS

ASK MIT CLIMATE: If the U.S. limits fossil fuel production at home, will we turn to cleaner sources of energy, or just import more oil and gas?

Supply-side restrictions, like shutting down new oil wells or gas pipelines, tend to lead to more imports and minimal impacts on greenhouse gas emissions—unless paired with other policies that limit demand for fossil fuels (MIT Climate Portal)

Milestones

Darby Kirven (MIT Joint Program, MIT Center for Global Change Science) started in April as the Development Officer in the Joint Program and CGCS. She has ten years' experience across food and beverage, healthcare, and public education sectors securing partnerships, supporting operational quality, and connecting a variety of stakeholders to scale program initiatives. Her roles at Build Health International and the South Carolina Governor's School for Science and Mathematics focused on sponsor recruitment, board relations, portfolio management and fundraising operations. She has a dual degree in Biology and International Affairs from the honors college at the University of South Carolina. She has served on the executive committee of the SC Governor's School Alumni Advisory board since 2020 and was raised on a farm in the southeastern US.

Peer-Reviewed Studies

Multiple biotic interactions establish phytoplankton community structure across environmental gradients (*Limnology and Oceanography*)

Phytoplankton thermal trait parameterization alters community structure and biogeochemical processes in a modeled ocean (*Global Change Biology*)

Machine learning based parameter sensitivity of regional climate models—a case study of the WRF model for heat extremes over Southeast Australia (*Environmental Research Letters*)

Quantifying the recreation use value of New England natural lands (*Environmental Challenges*)

Evolution of system connectivity to support food production in the Indus Basin in Pakistan (*PNAS*)

Deforestation as an anthropogenic driver of mercury pollution (*Environmental Science and Technology*)

Sustained growth of sulfur hexafluoride emissions in China inferred from atmospheric observations (*Nature Communications*)

Assessing Compounding Climate-Related Stresses and Development Pathways on the Power Sector in the Central U.S. (*Mitigation and Adaptation Strategies for Global Change*)

Net greenhouse gas balance in U.S. croplands: How can soils be part of the climate solution? (*Global Change Biology*)

Corn, Soybeans and Winter Wheat Water Requirements over the Contiguous United States between 2013 and 2021: The Application of the SEBALIGEE v2 Global Model (*Journal of Hydrology*)

A systems analysis of sustainability impacts of agricultural policies in India (*Earth's Future*)

Estimation of the atmospheric hydroxyl radical oxidative capacity using multiple hydrofluorocarbons (HFCs) (*EGUsphere*)

Equity implications of net-zero emissions: A multi-model analysis of energy expenditures across income classes under economy-wide deep decarbonization policies (*Energy and Climate Change*)

Deploying direct air capture at scale: how close to reality? (*Energy Economics*)

Mitigating Emissions in the Global Steel Industry: Representing CCS and Hydrogen Technologies in Integrated Assessment Modeling (*International Journal of Greenhouse Gas Control*)

Phytoplankton thermal trait parameterization alters community structure and biogeochemical processes in a modeled ocean (*Global Change Biology*)

Power sector impacts of the Inflation Reduction Act of 2022 (*Environmental Research Letters*)

Compounding uncertainties in economic and population growth 1 increase tail risks for relevant outcomes across sectors (*Earth's Future*)

Joint Program Reports

369. Climate-Related Stress-Testing and Net-Zero Valuation: A Case Study for Selected Energy-Intensive Companies

370. Machine Learning Driven Sensitivity Analysis of E3SM Land Model Parameters for Wetland Methane Emissions

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p 8(b): MIT

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(b) See p 7(a)
(c) See p 8(a)

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