GLOBAL CHANGES

MIT JOINT PROGRAM ON THE SCIENCE & POLICY OF GLOBAL CHANGE

SPRING 2023 NEWSLETTER

MIT JOINT PROGRAM
SCIENCE
POLICY
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: XLVI (46TH) GLOBAL CHANGE FORUM

Mar. 28–29, 2024 • Sponsor Meeting on Mar. 27

MIT Campus

Attendance is by invitation only.

SPRING 2023 GLOBAL CHANGES

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Perspectives: Empowering decision-makers to navigate climate and other crises

A response to the Synthesis Report of the IPCC Sixth Assessment

The March release of the Summary for Policymakers (SPM) of the Synthesis Report of the IPCC Sixth Assessment (AR6) provides a much-awaited integration of the major findings of the three Working Groups and three Special Reports comprising the AR6. Here, I present an informal "broad-brush" summary of the SPM and relate it to the Joint Program's ongoing development and application of its Integrated Global System Modeling framework and upcoming 2023 *Food, Water, Energy and Climate Outlook*.

The SPM concludes that human activity, led by greenhouse gas (GHG) emissions, has unequivocally caused global warming, with global surface temperature rising 1.1°C in the last 140 years. Human-caused climate change is already affecting many weather and climate extremes in every global region. Vulnerable communities, which have historically contributed the least to current climate change, are disproportionately affected. While adaptation planning and implementation have progressed across all sectors and regions, significant adaptation gaps remain. The SPM notes that current global financial flows for adaptation are insufficient for, and constrain implementation of, adaptation options, especially in developing countries. Policies and laws addressing mitigation have consistently expanded since the preceding Assessment (AR5). Global GHG emissions in 2030 implied by nationally determined contributions (NDCs) announced by October 2021 make it likely that warming will exceed 1.5°C during the 21st century and complicate efforts to limit warming below 2°C.

Regarding future climate change, risks and long-term responses, the SPM concludes that continued GHG emissions will most likely increase global warming to 1.5°C by 2040. Every increment of warming will intensify multiple and concurrent hazards, escalating risks (in many cases to higher levels than estimated in the AR5) and projected adverse impacts and related losses and damages. Climatic and non-climatic risks will increasingly interact, creating compounding and cascading risks that are more complex and difficult to manage. The likelihood of abrupt and/or irreversible changes increases with higher global warming levels. With increasing global warming, additional human and natural systems reach adaptation limits. Maladaptation could be avoided by flexible, multi-sectoral, inclusive, long-term planning and by implementation of adaptation actions, with co-benefits to many sectors and systems.


Ronald Prinn – Director, MIT Joint Program

The SPM also concludes that limiting human-caused global warming requires net zero CO_2 emissions. Cumulative carbon emissions until the time of reaching net-zero CO_2 emissions, along with the level of GHG emissions reduction this decade, will largely determine whether warming can be limited to 1.5°C or 2°C. All global modelled pathways that limit warming to 1.5°C (with >50% likelihood) with no or limited overshoot, and those that limit warming to

2°C (>67%), involve rapid, deep and, in most cases, immediate GHG emissions reductions in all sectors within this decade. For these two pathways, global net zero CO_2 emissions targets must be reached in the early 2050s and around the early 2070s, respectively. If warming exceeds a specified level such as 1.5°C, it could still gradually be reduced again by achieving and sustaining net-negative global CO_2 emissions. This would require additional deployment of carbon dioxide removal, compared to pathways without such overshoot, raising greater feasibility and sustainability concerns.

Addressing near-term responses, the SPM concludes that climate-resilient development integrates adaptation and mitigation to advance sustainable development for all, and is enabled by increased international cooperation. Needed actions include improved access to adequate financial resources, particularly for vulnerable regions, sectors and groups, and inclusive governance and coordinated policies. Deep, rapid and sustained mitigation and accelerated implementation of adaptation actions in this decade would reduce projected losses and damages for humans and ecosystems, and deliver many co-benefits, especially for air quality and health. Conversely, delayed mitigation and adaptation action would lock-in high-emissions infrastructure, raise risks of stranded assets and cost escalation, reduce feasibility, and increase losses and damages.

Rapid and far-reaching transitions across all sectors and systems are necessary to achieve deep and sustained emissions reductions and secure a livable and sustainable future for all. These system transitions involve a significant upscaling of a wide portfolio of mitigation and adaptation options. Accelerated and equitable action in mitigating and adapting to climate change impacts is critical to sustainable development. Regulatory and economic instruments can support deep emissions reductions and climate resilience if scaled up and applied widely. Finance, technology and international cooperation are critical enablers for accelerated climate action. If climate goals are to be achieved, financing for both adaptation and mitigation would need to increase manyfold. There is sufficient global capital to close the global investment gaps, but there are barriers to redirect capital to climate action. Enhancing technology innovation systems is key to accelerating widespread adoption of technologies and practices.

As outlined in the Joint Program's 2022 Annual Report, our plans for 2023 include significant advances in our seven core research focus areas: Earth Systems, Managed Resources, Infrastructure and Investment, Energy Transition, Policy Scenarios, Regional Analysis, and Multi-Sector Dynamics. These advances are directly relevant to the methods applied, or called for, in the Synthesis SPM. Also underway is the production of our 2023 *Food, Water, Energy and Climate Outlook*, which will examine uncertainties and scenarios that can inform and build upon the uncertainty and scenario (pathway) studies summarized in the SPM.

The climate crisis is one of several that humanity is confronting simultaneously. These include the Covid-19 pandemic, the Russian invasion of Ukraine, stressed energy markets, supply chain disruptions, currency inflation, and most recently the chaos in our banking and financial institutions. Despite all this turbulence, the world community must remain committed to achieving the critically needed transitions in our physical and social systems to mitigate dangerous global and regional environmental changes, while keeping our economies buoyant, equitable and sustainable. The Joint Program's Integrated Global System Modelling (IGSM) framework was developed precisely to analyze quantitatively these complex intertwined events and to proactively communicate science-based solutions to decision-makers in the public and private sectors.

—Ronald Prinn, Director

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.

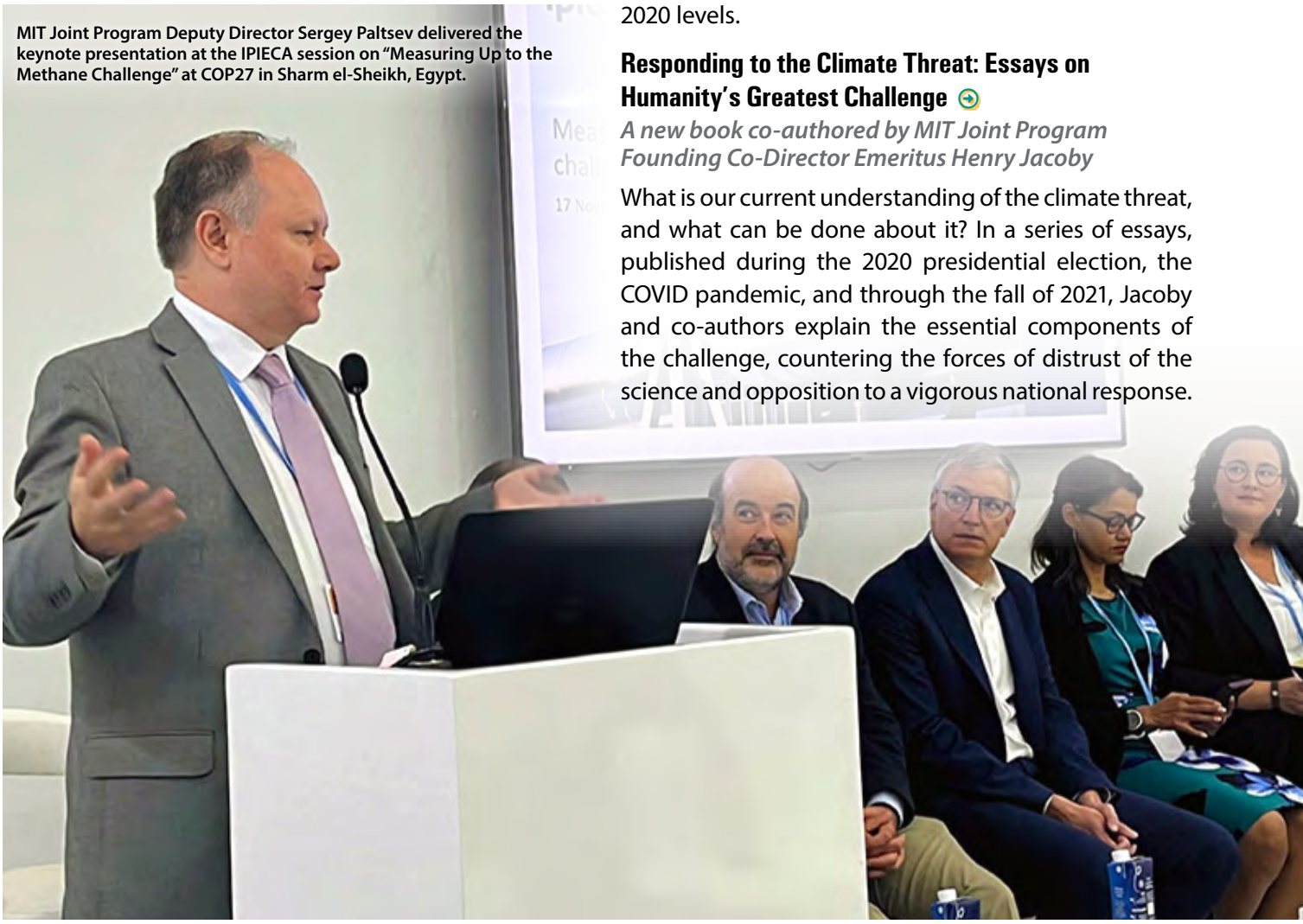
Earth Systems

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

MIT Joint Program at COP27

Reducing methane emissions is the fastest way to lower global temperatures in the near term

In a COP27 keynote presentation on the importance of proper methane emissions reduction options for climate stabilization, MIT Joint Program Deputy Director Sergey Paltsev stressed the need to accelerate mitigation actions. Using the projections from the Program's *2021 Global Change Outlook*, he illustrated that methane emission reductions should be implemented in addition to CO_2 reductions.



MIT Joint Program Deputy Director Sergey Paltsev delivered the keynote presentation at the IPIECA session on "Measuring Up to the Methane Challenge" at COP27 in Sharm el-Sheikh, Egypt.

A breakthrough on "loss and damage," but also disappointment, at UN climate conference

Delegates from MIT attended COP27 in Sharm el-Sheikh, Egypt, where international climate negotiations went down to the wire (MIT Office of the Vice President for Research)

MIT Joint Program Deputy Director Sergey Paltsev gave the keynote address at a Nov. 17 event on methane, where he noted the importance of methane reductions from the oil and gas sector to meeting the Global Methane Pledge goal to reduce methane emissions by at least 30 percent by 2030 compared to 2020 levels.

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

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

What is our current understanding of the climate threat, and what can be done about it? In a series of essays, published during the 2020 presidential election, the COVID pandemic, and through the fall of 2021, Jacoby and co-authors explain the essential components of the challenge, countering the forces of distrust of the science and opposition to a vigorous national response.

Infrastructure & Investment

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

Amundi increases its support to leading research initiatives on climate change mitigation and adaptation

Amundi has selected three research initiatives in 2023: EDHEC-Risk Climate Impact Institute, OS-Climate by Linux Foundation, and the MIT Joint Program on the Science and Policy of Global Change (Amundi)

Viewing research as fundamental to innovation in the responsible investment field, including the fight against climate change, Amundi thinks it's important to support key initiatives on climate mitigation and adaptation. The company has thus renewed its support to the EDHEC-Risk Climate Impact Institute and will start to support OS-Climate by the Linux Foundation as well as the MIT Joint Program.

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

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

2023 Economic Report of the President released (White House Council of Economic Advisors)

Report cites paper co-authored by MIT Joint Program researchers on climate effects on U.S. infrastructure

Falmouth, Massachusetts - Road flooding during a "bomb cyclone" storm.

Energy Transition

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

Staying the course: Achieving climate change goals in turbulent times

Key takeaways from the XLV (45th) MIT Global Change Forum

At the XLV (45th) MIT Global Change Forum on March 23-24, 2023, about 90 attendees from industry, academia, government and NGOs gathered at the Samberg Conference Center on the MIT campus to explore how the world can continue to pursue and achieve climate change goals amid turbulent times. Presenters addressed climate change challenges and solutions in six sessions.

MIT Joint Program at CERAWeek

Deputy Director Sergey Paltsev speaks on feasibility of 1.5°C target

Global leaders, activists and some scientists say the 1.5°C target is still feasible. Though it just barely remains in play, this aspirational target is at least technically possible. In a presentation on March 7 at CERAWeek, MIT Joint Program Deputy Director Sergey Paltsev discussed the need to accelerate actions by decision-makers seeking to lower CO_2 and other greenhouse gas emissions.

ENERGY TRANSITION - CONT'D

The underbelly of electric vehicles (Washington Post)
What goes into making EVs, where it comes from and at what human cost

America needs clean electricity. These states show how to do it. (Washington Post)
MIT Joint Program Principal Research Scientist Jennifer Morris comments on the viability of the nuclear power option

Could Air Someday Power Your Flight? Airlines Are Betting on It. (New York Times)
New technologies, including one fuel extracted from the atmosphere itself, could make flying more sustainable. But the challenges are many and the timeline is uncertain.

BEVs and FCEVs Can Meet Paris Agreement Goals (Power Electronics News)
Policymakers and manufacturers are working toward building new technologies to reduce the carbon footprint of cars

How Fully (Un)prepared Is America for a Supercharged Electric Vehicle Rollout in the Near Future? (Men's Journal)
MIT Joint Program Deputy Director Sergey Paltsev notes need to further reduce emissions associated with EV production and power sources

Energy transition could leave fossil energy producers and investors with costly stranded assets
Energy Futures highlights MIT Joint Program study

MIT Joint Program Deputy Director Sergey Paltsev interviewed in opening episode of Spanish public television documentary series "10,000 Days" (RTVE)
Episode explores technological innovations needed by 2050 to keep global climate targets in play


Public vehicle charging points in a row on the street.

Policy Scenarios

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

Improving health outcomes by targeting climate and air pollution simultaneously

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

An MIT-led research team has developed a climate/air-quality policy assessment tool that is both computationally efficient and location-specific. The tool could enable users to obtain rapid estimates of combined policy impacts on air quality/health at more than 1,500 locations around the globe — estimates precise enough to reveal the equity implications of proposed policy combinations.

Study: Shutting down nuclear power could increase air pollution

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

Policymakers are debating whether to retire the aging reactors or reinforce their structures to continue producing nuclear energy, which many consider a low-carbon alternative to climate-warming coal, oil, and natural gas. Now, MIT researchers say there's another factor to consider in weighing the future of nuclear power: air quality.

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) (Coverage: US News & World Report, HealthDay, The Hill, The Verge, Technology Review)

Wind power benefits climate, air quality, and public health by displacing emissions of greenhouse gases and air pollutants that would otherwise be produced by fossil-fuel-based power plants. An MIT study finds that health benefits associated with wind power could more than quadruple if operators prioritized reducing output from the most polluting power plants when wind energy is available.

EPA updates emissions standards for heavy-duty vehicles for the first time in 20 years (Popular Science)

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

Small oil rig in front of a wind farm in Texas.

Regional Analysis

Science and policy studies at subnational, national and multinational levels

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 team of researchers at MIT and Harvard University estimated which burning events, in what locations and at what times, produced the greatest increases in population exposure, premature deaths, and economic losses in India during the years 2003-09. Then they quantified how small-scale and targeted actions could reduce air pollution and health risks for the entire population.

Meet the climate hackers of Malawi (New York Times)

Article cites World Bank Country Climate and Development Report to which MIT Joint Program Research Scientist Kenneth Strzepek contributed

Multi-Sector Dynamics

Potential tipping points and transition states of Earth and human systems

Fuel oil delivery for home heating.

Hooked on heating oil: Maine's reliance on a dirty, expensive fuel (The Maine Monitor)

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

Finding 'hotspots' where compounding environmental and economic risks converge

Computational tool empowers decision-makers to target interventions

A computational tool developed by MIT Joint Program researchers pinpoints counties within the U.S. that are particularly vulnerable to economic distress resulting from a low-carbon energy transition. By combining county-level data on employment in fossil fuel industries with data on populations below the poverty level, the tool identifies locations with high risks for transition-driven economic hardship.

New Research Projects

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

Leader: Sergey Paltsev

Sponsor: Airbus Americas Inc. and LATAM Airlines Group S.A.

Duration: 1 year

We will assess pathways for emissions reduction in aviation and discuss potential science-based targets that airlines can impose on their path to carbon neutrality. In particular, we will analyze the scalability of biomass availability for sustainable aviation fuels (SAF) in Latin America. We also will investigate the driving forces and the impacts of land-use competition where bioenergy and natural sinks will rise in addition to the need for sustainable farming and food production. Tapping its established modeling, policy and technology expertise and prior relevant work, MIT will conduct an analysis of climate policies and likely carbon prices for the selected six Latin American countries: Mexico, Brazil, Colombia, Peru, Chile and Ecuador. Both the assessment of the current situation and future pathways in each country are critically important. MIT will assess the current situation and explore the pathways for SAF deployment under different policy options and technology deployment in these countries, with policy recommendations for local governments.

Development and Applications of GEOS-Chem Atmospheric Chemistry in CESM and MUSICA

Leaders: Sebastian Eastham and Daniel Jacob (Harvard University)

Sponsor: National Science Foundation

Duration: 3 years

This project will exploit and further develop the GEOS-Chem atmospheric chemistry capability within the NCAR Community Earth System Model (CESM). It will contribute individual GEOS-Chem components to the Multi-Scale Infrastructure for Chemistry and Aerosols (MUSICA), which is designed to provide a versatile multiscale atmospheric chemistry capability for the next generation of CESM. It will apply the unique resource of GEOS-Chem within CESM and through MUSICA to target pressing scientific questions related to our understanding of tropospheric ozone. The work will be driven by three objectives: (1) implement modular GEOS-Chem components into MUSICA for photolysis, chemical mechanism including adaptive mechanism auto-reduction, and wet deposition; (2) apply the GEOS-Chem capability within CESM to better

understand ozone air quality over East Asia and its connection to background tropospheric ozone; and (3) apply the GEOS-Chem capability within CESM to better understand aviation's effects on tropospheric ozone. In addition to the above objectives, this project will also provide support and documentation for CESM users to exploit the GEOS-Chem and Harmonized Emissions Component (HEMCO) capabilities within CESM, and it will contribute to software standards for MUSICA through early adoption of the infrastructure.

Analysis of National Hydrogen Supply Chain Scenarios

Leader: Sergey Paltsev

Sponsor: National Petroleum Council via MIT Energy Initiative

Duration: 1 year

This project will provide systems-level insights about the cost and performance parameters that low-carbon hydrogen technology must deliver to become a substantial contributor to decarbonization at the national scale. We will assess the role of hydrogen technology in a portfolio of mitigation options as a basis for strategies to advance the low- carbon hydrogen option. We will collaborate with MIT Energy Initiative researchers to enhance a multi-level platform, Sustainable Energy System Analysis Modelling Environment (SESAME), to explore the impacts of relevant technological, operational, temporal and geospatial characteristics of the energy system and various low-carbon hydrogen integration options. We will use a national energy-economic model (USREP) to examine long-term scenarios to estimate the importance of factors influencing hydrogen energy deployment and its role in decarbonizing the energy system and the economy.

Economy-Wide Impacts of Environmental Changes and Responses

Leader: Jennifer Morris

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

Duration: 3 years

Climate change presents a growing threat to economic development, exacerbating existing constraints to growth and creating new ones. It is increasingly important to incorporate climate and environmental considerations into constraints analysis and development decisions. Toward that end, we aim to support development planning by enhancing and utilizing our "impact channels" economic-biophysical modeling framework and facilitating its application to new counties. This framework is designed to estimate the impacts of environmental changes (including interactions with climate), as well as the effects of policies and adaptive actions, on economic growth at national (i.e. GDP) and sectoral levels under a wide range of scenarios. We seek to partner with MCC to facilitate the broad application of this framework and to make a greater impact by informing investment decisions. Within this partnership, we aim to demonstrate how our framework can support MCC analysis (e.g. CA and RCA), advance understanding of growth constraints in the climate-environmental space, and contribute to the public good by providing new scientific knowledge, useful analysis, and an open source modeling framework that can be broadly accessed and applied in support of sustainable development.

Global biomass availability for SAF production

Leader: Sergey Paltsev

Sponsor: US Federal Aviation Administration (via MIT Laboratory for Aviation and the Environment)

Duration: 1 year

Large-scale production of Sustainable Aviation Fuels (SAF) around the globe is needed to meet the aviation industry's ambitious decarbonization goals. Production scale-up will require identification of waste feedstocks and land for energy crop cultivation, sustainable farming and land-use practices, and investments in conversion capacity as well as fuel and feedstock logistics. Collaborating with the MIT Department of Aeronautics and Astronautics, we will assess global biomass availability, broken down by region, and the associated potential for SAF production with current and improved conversion technologies. Using the enhanced version of the MIT Economic Projection and Policy Analysis (EPPA) model, we will explicitly represent land use, land conversion, and land availability for biofuels for 18 world regions, including the USA, China, India, Europe, Africa, Brazil, Japan, Canada, Indonesia and others. In this assessment, land availability projections will be driven by explicit representation of land conversion costs, endogenous changes in land and agriculture intensification opportunities, and price-induced changes in energy efficiency in SAF production and transportation technologies.

Joint Program Reports

363. A Large Ensemble Global Dataset for Climate Impact Assessments

364. Temperature Implications of the 2023 Shell Energy Security Scenarios: Sky 2050 and Archipelagos

365. Building a composite indicator for biodiversity through supervised learning and linked indicator sets

Peer-Reviewed Studies

Impacts of wind power on air quality, premature mortality, and exposure disparities in the US (*Science Advances*)

A Tool for Air Pollution Scenarios, TAPS v1.0, to enable global, long-term, and flexible study of climate and air quality policies (*Geoscientific Model Analysis*)

Economic Dispatch Considering Hourly Capacity Allocation with a Variable Renewable and Hydro-Based Generation Portfolio (*Energy and Power Engineering*)

Air quality impacts of crop residue burning in India and mitigation alternatives (*Nature Communications*)

From Stockholm to Minamata and beyond: Governing mercury pollution for a more sustainable future (*One Earth*)

The human–technical–environmental systems framework for sustainability analysis (*Sustainability Science*)

Evaluating atmospheric mercury (Hg) uptake by vegetation in a chemistry-transport model (*Environmental Science: Processes and Impacts*)

What are the likely changes in mercury concentration in the Arctic atmosphere and ocean under future emissions scenarios? (*Science of the Total Environment*)

Statistical and machine learning methods for evaluating trends in air quality under changing meteorological conditions (*Atmospheric Chemistry & Physics*)

When private governance impedes multilateralism: The case of international pesticide governance (*Regulation & Governance*)

A renewed rise in global HCFC-141b emissions between 2017–2021 (*Atmospheric Chemistry & Physics*)

Rapid estimation of climate-air quality interactions in integrated assessment using a response surface model (*ACS Environmental Au*)

Nuclear Power Generation Phaseouts Redistribute U.S. Air Quality and Climate Related Mortality Risk (*Nature Energy*)

Pumped-hydro storage plants influencing the optimal hourly dispatch in hydro-thermal systems with massive integration of variable renewable energy (*Electric Power Systems Research*)

Assessing Compounding Risks Across Multiple Systems and Sectors: A Socio-Environmental Systems Risk-Triage Approach (*Frontiers in Climate*)

Clean energy transition in the Turkish power sector: A techno-economic analysis with a high-resolution power expansion model (*Utilities Policy*)

Influence of forest infrastructure on the responses of ecosystem services to climate extremes in the Midwest and Northeast United States from 1980 to 2019 (*Frontiers in Environmental Science*)

Biogeochemical River Runoff Drives Intense Coastal Arctic Ocean CO_2 Outgassing (*Geophysical Research Letters*)

Thermal Responses in Global Marine Planktonic Food Webs Are Mediated by Temperature Effects on Metabolism (*JGR Oceans*)

Designing climate policy mixes: Analytical and energy system modeling approaches (*Energy Economics*)

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Our work is funded by an international partnership of government, industry and foundation sponsors, and by private donations. Our sponsor consortium provides the long-term substantial commitment needed to support our dedicated and specialized staff, and to realize a coordinated integrated research effort.

Federal Sponsors

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- MIT Energy Initiative (MITEI)
- MITEI Future Energy Systems Center consortium
- MIT Int'l Science and Policy Initiatives (MISTI) Imperial College Seed Fund
- MIT Office of Sustainability
- MIT Office of the Vice President of Research
- Morgan Stanley
- Murphy
- Novartis
- Shell

Global Changes is published biannually by the MIT Joint Program on the Science and Policy of Global Change, and is made available to the public one month after its release to our program membership.

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