

Options

WINTER 2021

PLOTTING THE FUTURE

*Scenarios help explore
climate change by imagining
different futures*

WHAT IS SYSTEMS ANALYSIS?

*Why this flexible, shapeshifting
discipline is well-placed to
address climate change*

PEOPLE AT THE HEART OF CLIMATE CHANGE

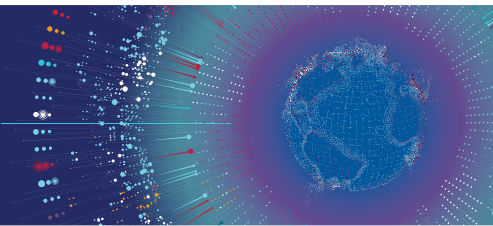
A systems
look at how
our decisions are
driving global
change

THE FUTURE OF THE RIVER IS IN YOUR HANDS

*Role-playing simulation games
as a tool to engage stakeholders*



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FROM THE EDITORIAL TEAM

The 2021 United Nations Climate Change Conference, also known as COP26, comes at a critical time for humanity and is an unprecedented opportunity for the world to come together to address the threat to our continued existence on this planet that is climate change. This special edition of *Options* highlights the work of IIASA researchers on the subject.

Our cover feature takes a systems look at humanity's role in the climate crisis. We are both the cause and victims of climate change, and it therefore stands to reason that we should also be part of the solution (pages 12-15). Our second feature explains the role of scenarios in exploring climate change and its impacts, and how these stories of future Earth could help to reveal how we might prevent global tragedy (pages 10-11). While systems analysis is uniquely suited to address complex global issues like climate change, it is difficult to pin down. In this issue, you can read all about how the flexible, shapeshifting nature of this discipline is actually also its superpower (pages 16-17).

Please get in touch with us via email if you would like to share your thoughts on articles in this issue or if you have ideas for topics that you would like to see featured in future issues.

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ABOUT OPTIONS

Options magazine features recent IIASA research and activities.

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News in brief



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Finding the BEST way to store renewable energy on islands

The road towards a carbon neutral future is paved with renewable energy. The drawback of relying on clean energy sources, however, is that the energy supply doesn't always meet our demands – the sun doesn't always shine when we need electricity.

Batteries are the most common way to store renewable energy, but the associated high costs and environmental damage prompted scientists to look for different solutions. IIASA researcher Julian Hunt and colleagues devised an innovative energy storage system, called Buoyancy Energy Storage Technology (BEST) that relies on hydrogen gas compression. In this system, a large square of high-density polyethylene pipes containing hydrogen is lowered to the seafloor using an electric motor, compressing the gas. When the tubes are allowed to rise driven by buoyancy, the motor turns into a generator and produces electricity.

"While the investment cost of energy storage with batteries today is around US\$ 150/kWh, the cost of BEST is just US\$ 50 to US\$ 100 per kWh," says Hunt. "Given that the cost of installed capacity for batteries is smaller than in BEST systems (US\$ 4 to US\$ 8 million per kilowatt), battery and BEST systems could be operated in conjunction to provide energy storage for a coastal city or for an offshore wind power plant."

As an added benefit, BEST systems also provide a solution for compressing hydrogen at a cost 30 times lower than traditional hydrogen compressors. Hunt envisions the transportation of the compressed hydrogen through deep underwater pipelines connecting continents or by towing deep underwater vessels with compressed hydrogen and ballast by a ship on the surface.

"Such deep pipelines and vessels combined with BEST systems have the potential to become the backbone that sustains the future hydrogen economy," Hunt concludes.

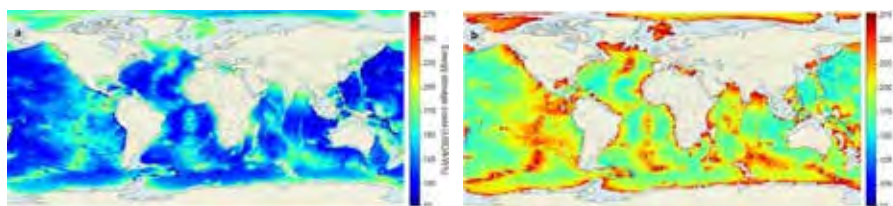


Figure: World potential of BEST with (a) air and (b) hydrogen as the storage medium. The greater the depth, the higher the BEST potential.

By **Fanni Daniella Szakal**

Further info: pure.iiasa.ac.at/17238 | www.iiasa.ac.at/news/21-energy-storage

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CLIMATE AND THE SPREAD OF COVID-19

World maps show that COVID-19 is less prevalent in countries closer to the equator. Joining an international collaboration, IIASA researchers found that a one-degree increase in absolute latitude is associated with a 4.3% increase in cases per million inhabitants as of 9 January 2021. COVID-19 cases are expected to decline during summer months, implying that higher average temperatures support public health measures containing SARS-CoV-2 without, however, replacing them.

pure.iiasa.ac.at/17190

FINDING PATHWAYS FOR SUSTAINABLE DEVELOPMENT IN AFRICA

In partnership with the Belmont Forum, a new project will develop novel tools and capacities to understand and manage interconnections between the Sustainable Development Goals and explore bottom-up sustainable development pathways for the African countries. Transformation pathways will take into account African local socioeconomic context, capacities, and priorities to facilitate the achievement of the 2030 Agenda.

www.iiasa.ac.at/news/21-Africa

TO ACHIEVE THE SDGS, WE NEED BETTER DATA

The global campaign, Data for Change, demonstrates how more and better data and statistics are an accelerator for sustainable development. The campaign aims to present how high-quality statistics are leading to life-changing policies and advancing progress towards the UN Sustainable Development Goals. This was illustrated in a successful data driven campaign aimed at cleaning Ghana's coasts.

www.iiasa.ac.at/news/21-CS4SDG

Informing global climate policy

Pioneering IIASA research on climate change since the 1970s has played a key role in contributing to the work of the Intergovernmental Panel on Climate Change (IPCC) - the leading global body for the assessment of climate change, its impacts, and response options. IPCC publications provide decision makers with a clear and scientific view on the current state of knowledge of climate change and its potential environmental and socioeconomic impacts.

Through its continued investment and leadership in interdisciplinary and integrated research, IIASA publications provide rich material for the assessment reports and its scientists are well positioned to provide expertise in deciphering the large and complex challenge that is climate change. It is this recognition that has resulted in numerous IIASA scientists being enlisted as coordinating lead authors, lead authors, and reviewers of IPCC publications over the years.

The institute continues its tradition of involvement in the IPCC's work in the upcoming Sixth Assessment Report (AR6). The report will be a comprehensive assessment of the science related to climate change and will inform policymakers, international climate negotiators, and other stakeholders around the world. In total, 721 authors, including several IIASA researchers have been selected from 2,858 experts representing 105 countries, who were nominated by governments and IPCC observer organizations.

IIASA was also represented at several events during the 2021 UN Climate Conference (COP26) in Glasgow, including at least two side events co-organized by IIASA.

By **Ansa Heyl**

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Digital platforms offer new resilience

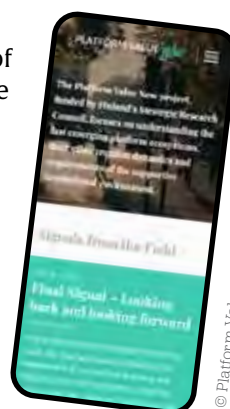
The Digital Revolution has changed the way businesses operate since its adoption in the latter half of the 20th century. Now, digital platforms are changing the way we do business, offering a resilience previously unseen in an uncertain world.

The essence of a digital platform like Airbnb is to enable connections between producers and consumers, letting people take on both roles to become “prosumers”. A successful platform allows multi-sided interactions and gathers a sort of ecosystem of businesses around it.

Funded by the Finnish Strategic Research Council, IIASA teamed up with five other research institutions in the Platform Value Now project. The project aimed to understand the shift from traditional business models to fast emerging platform economic ecosystems and analyzed them to develop efficient methods and tools for platform-centric economic ecosystems management.

The project also investigated the resilience of digital ecosystems in light of unexpected events like COVID-19 and the recent Suez Canal blockage, which are a stark reminder of how events can derail society and businesses, especially in an interconnected global economy.

“We never know what will happen next. That is why we must build resilience. An ecosystem is much more resilient than an individual company,” explains Leena Ilmola-Sheppard, IIASA Guest Emeritus Research Scholar. “Rapid technology development can add future uncertainty, but a decentralized diverse platform ecosystem can provide resilience when resources are strained, or a new threat emerges.”



© Platform Value Now

By **Neema Tavakolian** **Further info:** www.iiasa.ac.at/news/21-platform

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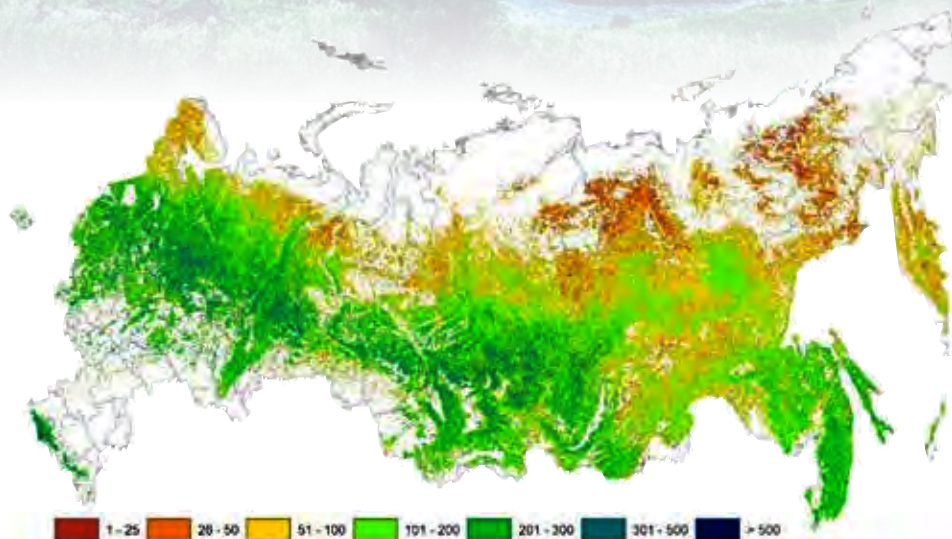


Figure: Predicted mean forest growing stock volume (m³ ha⁻¹) for the year ca 2014

Russian forests could be key in the fight against climate change

Home to almost one-quarter of total forests globally, Russia can make a huge global impact regarding climate mitigation. When the Soviet Union dissolved, so too did the consistent tracking of its forests. Based on current data, there appears to be a significant information gap since 1988, showing little to no changes in the reported biomass of Russia's forests. Remote sensing data however, paints a different picture.

With the help of international colleagues and Russian experts, IIASA researchers produced new estimates of biomass contained in Russian forests, confirming that there has been a substantial increase over the last few decades. The first cycle of the Russian National Forest Inventory (NFI) was finalized in 2020, allowing the team to combine their remote sensing data with freshly produced Russian reports.

"Using advanced analysis techniques for biomass calculations, we discovered that carbon sequestration in live biomass of managed forests between 1988 and 2014 is 47% higher than reported in the National Greenhouse Gases Inventory. This investigation confirms the importance and impact these forests have in the fight against climate change," says study lead author Dmitry Shchepashchenko.

While Russian forests and forestry have great potential in terms of global climate mitigation, it is important to highlight that with the climate becoming more severe, as in recent years, resulting forest disturbances might severely reduce these gains. Close collaboration of science and policy would therefore be critical to elaborate and implement an adaptive and sustainable forest management.

"We are talking about the country hosting the world's largest forest area. Imagine what just a few percent up or down of forest biomass available would do. Its consequent carbon sequestration potential can make huge impacts globally," notes study coauthor, Florian Kraxner.

By **Neema Tavakolian** Further info: pure.iiasa.ac.at/17270

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SUPPORTING SUSTAINABLE DEVELOPMENT IN THE AGRICULTURAL SECTOR

On this year's World Day to Combat Desertification and Drought, IIASA, the Food and Agriculture Organization of the United Nations (FAO), and the Environmental System Research institute (ESRI) launched the Global Agro-Ecological Zones version 4 (GAEZ v4). This research tool supports sustainable development in agriculture by assessing global land and water resources.

www.iiasa.ac.at/news/21-agriculture

BUILDING FAIRNESS INTO DECISION MAKING

FairSTREAM, a new IIASA Strategic Initiative, will develop and demonstrate a co-production methodology for including fairness alongside efficiency in the development of sustainable policy options in the food, water, and biodiversity nexus.

www.iiasa.ac.at/news/21-fairSTREAM

CLOSING KNOWLEDGE GAPS FOR SUSTAINABLE AGRICULTURE

Pathways towards sustainable agriculture and the feasibility of measuring their efficacy remain elusive. The Sustainable Agriculture Matrix (SAM) Consortium, an IIASA project funded under the Belmont Forum's joint Collaborative Research Action on Pathways to Sustainability, is exploring new ways of making agricultural sustainability better measurable, bringing together researchers from various disciplines and stakeholders from around the globe.

www.iiasa.ac.at/news/21-sustainableagriculture

Global areas of importance for biodiversity, carbon, and water

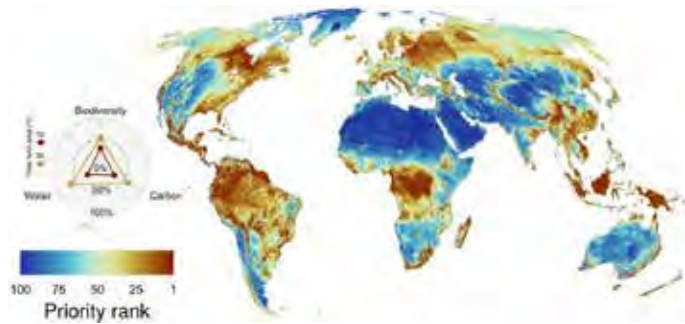


Figure: Global areas of conservation importance for terrestrial biodiversity, carbon and water.

Natural climate solutions are high on the UN's climate agenda, but as biodiversity conservation targets draw closer, we are collectively failing to conserve the world's biodiversity and halt further global warming.

As part of the Nature Map Project, IIASA researchers revealed that managing a strategically placed 30% of land for conservation could yield major achievements, including safeguarding 62% of the world's vulnerable carbon, 68% of all fresh water, and reducing the extinction risk of over 70% of all terrestrial vertebrate and plant species.

The study demonstrates that jointly planning for biodiversity, carbon, and water reveals key broad areas of importance in a single integrated map, thus going beyond any ranking of individual assets.

"Our methods, data, and the global ranked maps developed in this study are meant to be used as a decision support tool for conservation initiatives, decision makers, and donors aiming to identify broad regions for investments. The study lays the groundwork for a new generation of integrated planning exercises to inform conservation options across scales," explains Martin Jung, who headed the study.

"Our work shows that when it comes to identifying new areas to manage for conservation, quality is more important than quantity. Safeguarding biodiversity will require strategic placement of conservation interventions using spatial planning tools like those developed for this project and, crucially, requires enabling stewards to effectively manage these areas," concludes Piero Visconti, a study coauthor.

By **Neema Tavakolian**

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COVID-19's impact on energy demand could help meet climate targets

The pandemic-related drop in greenhouse gas emissions in 2020 was likely the largest on record in a single year. While notable, this huge drop in emissions does not provide much information regarding challenges to meet climate targets, because it does not paint a clear picture for the future as societies recover.

IIASA researchers examined alternative scenarios of recovering activity levels and the energy demand paired with that. This work started from a bottom-up assessment of changes during lockdowns and then assessed how selectively maintaining certain practices might alter climate mitigation challenges.

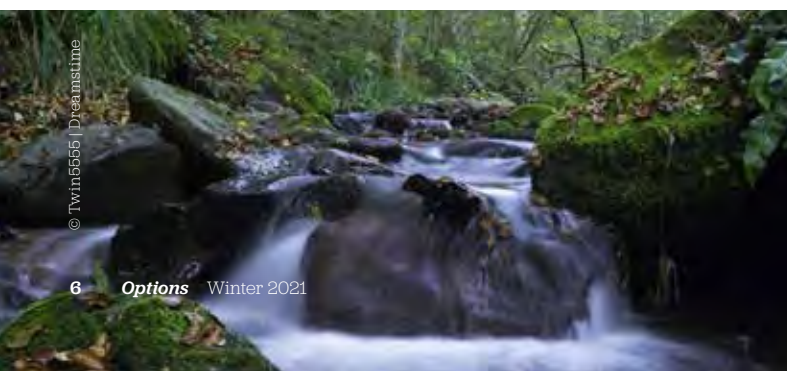
"Many people have been wondering what the large changes in societies that came with the pandemic and its lockdowns mean for climate change. If societies are just moving back to old practices, then there is virtually no effect. However, if some of the changes in energy-use practices persist, climate mitigation challenges will be affected," says Jarmo Kikstra, lead author of the study.

The researchers examined four different scenarios each with consistent assumptions and changes in energy demand in buildings, transport, and industry. Their results indicate that a low energy demand recovery could help to partially alleviate some of the challenges in the energy transition required to stay on track towards meeting Paris Agreement climate targets.

"A silver lining to the COVID-19 cloud is that reaching climate targets becomes a bit more achievable if we can sustain some of the lower-carbon practices forced upon us by lockdowns," concludes coauthor Charlie Wilson.

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How will we deal with carbon debt?

As the carbon budget for the 1.5°C climate mitigation scenario is running out, we need to solve the issue of the carbon debt that will inevitably build up if we continue business as usual. IIASA researchers and international colleagues have developed a new framework for a net-negative carbon economy, helping us achieve climate targets.

In climate change discussions, the Paris agreement and 1.5°C are the buzzwords today. The Sixth Assessment Report of the United Nations Intergovernmental Panel on Climate Change forecasts that warming will have reached 1.5°C already in the early 2030s – even if emissions are radically reduced in the near future. Most countries agree on the urgent need to act and emission targets are part of several ambitious international agendas, such as the recently adopted Climate Law by the European Union that not only aims to reach net-zero emissions by 2050, but plans to go into net-negative thereafter.

In practice however, we are still emitting more carbon than we should and the carbon budget for the 1.5°C warming limit will probably be exhausted within this decade. At that point, we will start building up a carbon debt – a debt that has to be dealt with if we want to avoid a climate catastrophe. Despite the existing agendas to achieve net-zero emissions, there is generally a lack of strategy to repay this potentially costly debt.

To bridge the gap between words and action, IIASA researchers and international colleagues have devised a practical framework for a future net-negative carbon economy. The researchers imagined a system, where carbon debt would be managed through so-called carbon removal obligations that hold corporations that continue to emit large amounts of carbon dioxide legally responsible to remove an equivalent quantity of carbon in the future.

To deal with the risk of carbon debtors, the new emission trading schemes would treat carbon debt like financial debt and impose interest on it – as if corporations would pay a rental fee for temporarily storing carbon dioxide in the atmosphere.

“Carbon removal obligations completely change how we see carbon dioxide removals: from magical tools to enable a 30-year long period of the grand atmospheric restoration project, to a technology option that is developed and tested today and flexibly and more incrementally scaled throughout the 21st century and possibly beyond,” says IIASA researcher and study coauthor Fabian Wagner.

“Instead of overburdening future generations, carbon removal obligations imply a much more

equitable distribution of financial flows and costs over time and it seems they will need to be an integral part of any successful climate mitigation policy in the future,” adds study lead author Johannes Bednar.

This research highlights the need for immediate action to establish responsibility for carbon debt, hopefully influencing climate policy, for example, during the upcoming revision of the EU Emissions Trading Scheme.

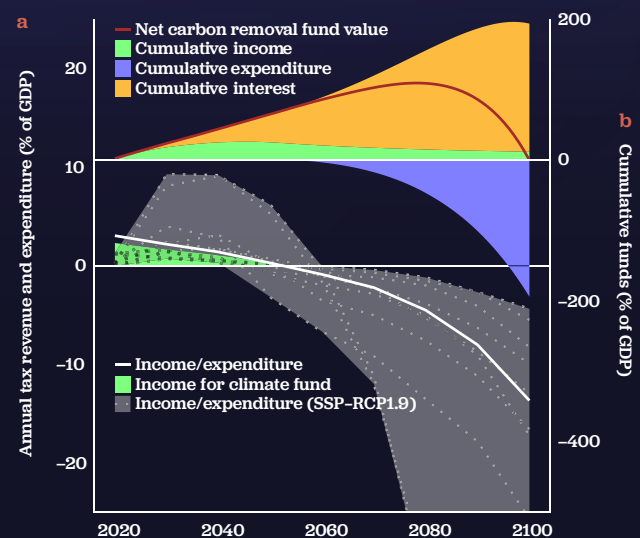


Figure: a. Bottom, public income and expenditure from a tax on net emissions expressed as a percentage of GDP. b. Top, cumulative payments into the net carbon removal fund (green) and interest (orange) in theory pay exactly for cumulative tax expenditure (blue), such that the net value of the fund (brown solid line) gets exhausted as the warming target is achieved in 2100.

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Science into policy

Building the road to European climate neutrality

Strong policies are needed if the European Union (EU) wants to reach its climate targets. IIASA research has underscored much of the framework for the policies amended in EU climate legislation, including the ‘Fit for 55 package’.

Climate change is an unfortunate certainty and at today’s emission rates, it is only getting worse. Any chance of successfully addressing the problem will require international cooperation and collectivism to affect the transformational changes needed worldwide in our economies, societies, and industries.

The EU has set its own goals for dealing with climate change under the European Green Deal, which aims to cut emissions by 55% by 2030 with the goal of reaching climate neutrality by 2050. IIASA science has backed the “Fit for 55 package”, which contains legislative proposals to revise the climate policies needed to get the EU on track to meet the goals outlined in the Green Deal.

IIASA models have provided substantial scientific support for the “Fit for 55 package”. Using models such as the Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) Model, the Global Biosphere Management Model (GLOBIOM), and the Global Forest Model (G4M), researchers were able to analyze and calculate valuable information for the European Commission as it prepared policy proposals and revisions.

The G4M and GLOBIOM models were used to assess mitigation potentials from greenhouse gas emissions for the land use, land-use change, and forestry sector and contributed to the assessment of afforestation costs included in the New EU Forest Strategy, another part of the “Fit for 55 package”.

“As climate change escalates, we need our climate policies to be both ambitious and comprehensive. It is important to account for emissions and sequestration potentials from the land sector and its interlinkages with renewable energy production,” says

Andre Deppermann from the IIASA Integrated Biosphere Futures Research Group.

The GAINS model was used to provide the “Fit for 55 package” with country-specific mitigation pathways for reductions in the non-CO₂ greenhouse gases like methane, nitrous oxide, and fluorinated gases for each of the 27 EU countries.

“Climate neutrality means reducing greenhouse gases across all sectors, not only phasing out carbon dioxide emissions in the energy sector,” says Lena Höglund-Isaksson from the IIASA Pollution Management Research Group.

The GAINS model was also used to assess the impacts on air pollution from implementing the “Fit for 55 package”.

“We have reached a point now where climate change is already happening and aspects of its detriment are inevitable. However, strong policies backed by comprehensive research and transparent processes instill trust in policy solutions that can improve the direction we are headed,” she concludes.

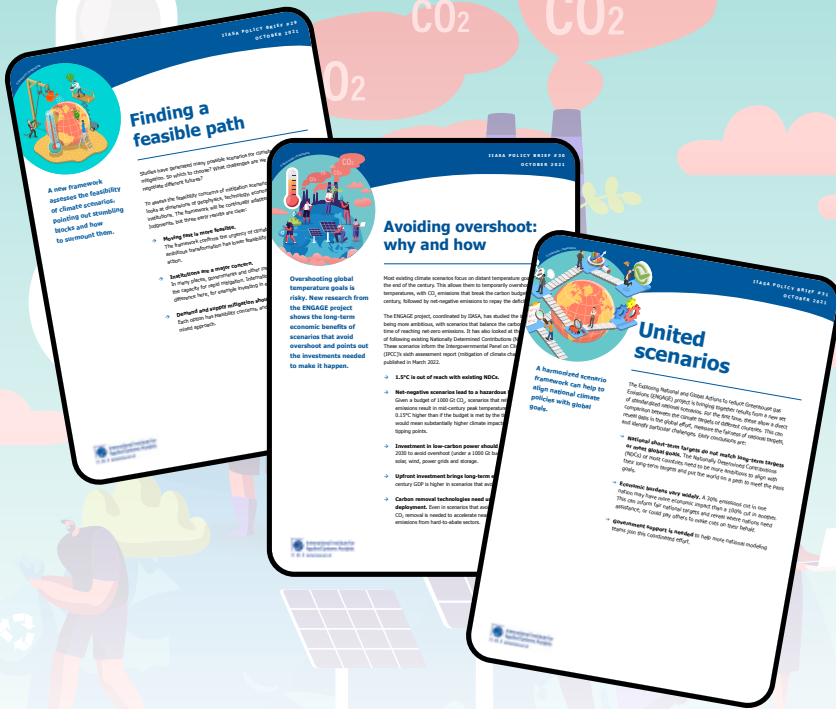
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Engaging on the road to net-zero

At COP26, IIASA researchers presented their latest research into cost-effective, technologically sound, socially and politically feasible pathways for meeting the objectives of the Paris Agreement. The research was conducted by interdisciplinary teams of scientists brought together from across the community by Elina Brutschin and Keywan Riahi, both from IIASA, to explore net-zero futures and their feasibility. A series of three policy briefs summarize the main policy implications of the work.

The first policy brief presents a new, flexible, framework to assess aspects of climate scenarios that raise feasibility concerns, and how to overcome these. Three main results stand out: immediate ambitious transformation has lower feasibility concerns than delayed action; the capacity of governments and other institutions to guide rapid mitigation is a major concern; and balanced mitigation strategies between demand and supply sides raise fewer feasibility concerns.

The second policy brief looks at global climate scenarios, highlights the long-term economic benefits of scenarios that avoid emission and temperature overshoot, and points out the short-term investments needed to make it happen. It also shows that following existing Nationally Determined Contributions (NDCs) until 2030 will close the road to limiting warming to 1.5°C.

The final policy brief in the series zooms in on national decarbonization pathways and evaluates the effect of current policies, while also exploring the possibilities for more ambitious reduction targets to inform long-term strategies and net-zero greenhouse gas emissions targets.

All these scenarios along with the new feasibility framework will inform the Intergovernmental Panel on Climate Change (IPCC)'s sixth assessment report focusing on the mitigation of climate change, which is due to be published in March 2022.

By **Ansa Heyl**

Further info: www.iiasa.ac.at/policybrief/29 | www.iiasa.ac.at/policybrief/30
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WEIGHING IN ON THE CONVERSATION AROUND LOSS AND DAMAGE

An IIASA policy brief prepared for the UK Presidency's *Adaptation and Loss and Damage Day* and an NGO-led side event at the 2021 UN Climate Conference (COP26) in Glasgow, proposes a comprehensive climate risk finance framework that expands the focus of Loss and Damage with provisions for transformational risk management, and curative options to address the residual impacts of climate change. The framework can be applied at different scales and offers an entry point for an extensive approach that informs international negotiations on Loss and Damage and adaptation, as well as country-level policymaking.

www.iiasa.ac.at/policybrief/32



LINKING CLIMATE CHANGE MITIGATION AND SUSTAINABLE DEVELOPMENT

A new report by the NewClimate Institute, IIASA, and PBL Netherlands provides an assessment of progress in policy implementation and mitigation commitments for 26 major emitting countries and regions up to 2030. Emissions are projected to remain above 2005 levels in most countries, but the report concludes that 16 of the 26 countries and regions analyzed are on track, or close to achieving the targets they had set for themselves as part of their Nationally Determined Contributions (NDCs). Further action is however required in several of the countries examined.

pure.iiasa.ac.at/17481

Plotting the future

Scenarios are essential for exploring climate change. These stories of future Earth help to reveal how we might prevent global tragedy.

By Stephen Battersby

We need climate scenarios because the future is uncertain and complex. We cannot know what will happen to populations, international relations, societies, economies, ecosystems, and technologies. Much of the uncertainty comes from today's choices, which can only be explored by posing "what-if" questions. So climate scientists have become storytellers, crafting consistent plotlines that span a range of futures and compare policy outcomes. Some of these scenarios have grisly ends; others are hopeful but risky; and some of the latest are telling a new kind of mitigation story, which turns out to benefit both climate and economy, and might be more feasible too.

The world's a stage

The storytelling tradition goes back several decades... but let's skip the prologue. In 2000, the Intergovernmental Panel on Climate Change (IPCC) published its landmark Special Report on Emissions Scenarios (SRES), led by then IIASA Transitions to New Technologies Program Director, Nebojsa Nakicenovic. This laid out shared scenarios, which would allow research teams to base their studies on well-established plot outlines, and compare results more easily.

It started with four broad storylines. The A1 world sees rapid economic growth, technological progress, and internationalism, with regional incomes converging. B1 adds a shift to cleaner technologies and service economies. A2 tells of stronger regional differences, with higher population growth. B2 imagines more focus on local solutions to sustainability.

Each storyline yields some detail on climate drivers such as GDP and energy efficiency. These numbers were fed into various integrated assessment models (IAMs), which combine economics, demographics, energy systems, and climate, to generate full scenarios – projecting how the global system of systems might evolve.

The conclusion was grim. The IPCC's third assessment report in 2001 revealed that an A2 world was heading for catastrophe, probably warming by more than 4°C relative to preindustrial levels. Even in the most climate-friendly storyline, B1, scenarios clustered around warming of roughly 2.5°C – still a sorry scene for the planet.

Enter the matrix

In the 2010s, researchers created a more sophisticated set of stories, based on a matrix framework with one axis for emissions, and another for socioeconomic possibilities.



Four Representative Concentration Pathways (RCPs) present a range of climate futures, running from hot to cool: from very high emissions in RCP 8.5 down to what was then considered an ambitious mitigation pathway, RCP 2.6. The numbers labelling each RCP give the climate forcing in 2100, that is, the Earth's energy imbalance owing to human greenhouse gas emissions, in watts per square meter.

On the other axis of the matrix, the Shared Socioeconomic Pathways (SSPs) tell of five future worlds. SSP1 is a sustainable, equitable path, with a focus on wellbeing over wealth. SSP2 is a middle-of-the road tale, with moderate improvements in efficiency and sustainability, but with trends mainly following historical patterns. SSPs 3, 4, and 5 respectively tell of regional rivalry, inequality, and fossil-fueled development.

To develop a detailed scenario, you choose one SSP (the setting of the story) and constrain emissions according to one RCP (the story arc). Then a model can try to work out the most cost-effective set of mitigation options that fit both pathways.

Sometimes, that is impossible. For example, there is no way to force the SSP3 regional rivalry story to be compatible with RCP2.6. This is a crucial insight from the matrix era: a wrong turn in global socioeconomic development would make deep mitigation impossible.

Alarms and excursions

The Paris Agreement gave scenario-makers a clear and specific goal: limit global warming to well below 2°C, preferably 1.5°C. But by aiming at the Paris goals only at the end of the story, in 2100, almost all recent pathways and scenarios have taken us on a narrative rollercoaster. They overshoot temperatures in the middle of the century, then swing back down by requiring that global emissions go net-negative. This requires carbon removal technologies, such as bioenergy with carbon capture and storage (BECCS), on a huge scale.

This is a risky plot device, letting the world stray into danger and then expecting the cavalry to ride in and save us. While carbon removal is likely to be an essential mitigation tool, it might turn out to be unfeasible at the scale required by this narrative. Meanwhile, there would be serious impacts during the overshoot, increasing climate hazards for millions. A temporary temperature rise could also lead to permanent shifts in climate or ecology. Once a species or an ecosystem has gone extinct, no amount of negative emissions will bring it back.

Such an adventure into unknown territory may make for an exciting story, but that's not what the planet needs right now. In 2019, a team led by IIASA researcher Joeri Rogelj set out principles for telling more soothing stories, which pay attention to the journey as much as the ending. In their framework, the goal is to limit peak temperature. Emissions cuts bring the world to net-zero without breaking the carbon budget, which means there is no temperature overshoot.

As well as reducing climate hazards, this could bring economic benefits. Avoiding overshoot needs ambitious, rapid mitigation in the short term, and that takes a lot of investment – but it pays off in the long-run, according to a study by IIASA Energy, Climate, and Environment Program Director, Keywan Riahi and colleagues. Scenarios avoiding overshoot lead to higher global GDP by the end of the century. That is without even allowing for the economic impacts of climate change, which would be worse in overshoot scenarios.

Recent scenarios confirm a more general point: action is urgent. The study found that unless countries strengthen their short-term climate commitments (Nationally Determined Contributions), then 1.5°C is out of reach. Moving fast may also be more feasible. A study by IIASA researcher Elina Brutschin and colleagues examined pitfalls that could derail mitigation, such as ineffective governance and stranded assets, and found that rapid early mitigation lessens such concerns.

The moral of these new stories is clear: **don't waste time.**



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By Ansa Heyl

PEOPLE AT THE HEART OF CLIMATE CHANGE

Human activity is the main cause of climate change. It is also people who endure the worst of its impacts. It is a matter of utmost urgency that people are part of the solution.

FLOODED SUBWAY TUNNELS AND SUBURBS, UNSTOPPABLE WILDFIRES RAGING ACROSS THE COUNTRYSIDE, AND HEATWAVES AND HURRICANES WREAKING HAVOC IN COMMUNITIES. THESE ONCE-IN-A-CENTURY EVENTS HAVE BECOME NOT ONLY MORE FREQUENT BUT ALSO MORE INTENSE AROUND THE WORLD. AS MORE AND MORE PEOPLE ARE AFFECTED, IT IS UNDENIABLE THAT THE EFFECTS OF CLIMATE CHANGE ARE BEING FELT ACROSS THE GLOBE.



Research shows that more than 24 million people on average have had to leave their homes due to climate and weather-related events every year since 2008, and if such events keep increasing in frequency and severity, indications are that rates of movement will also increase. However, not everyone can afford to move and there is a risk that disadvantaged communities in affected regions will find themselves caught in a “mobility trap”. Climate

change is in fact already disproportionately affecting the world’s most vulnerable populations, exacerbating existing health threats, and creating new public health challenges. The effects of climate change will not only compound and magnify existing inequalities, but its effects will increase in severity over time, affecting current and future generations.

WEATHERING THE STORM

Some argue that an important response to climate impacts is simply moving away from affected areas. However, this presents multiple challenges – both for the people moving and for the communities where they end up. Add to this the fact that there seems to be little policy planning for potential displacement and population movements and that impacts are mostly only dealt with after they happen – mainly by overstretched local governments and charities – it seems that a perfect storm is brewing.

IIASA researchers have long been studying the intricate links between climate change and people. Systems science is particularly well suited to explore issues in this regard, as climate impacts can potentially affect population size, composition, and where people

live, while such changing demographics can in turn influence global climate systems, as human activities contribute to and drive climate change.

The Population Dynamics under Global Climate Change (POPCLIMA) Project funded by a European Research Council Consolidator Grant and led by IIASA Population and Just Societies Program Director Raya Muttarak, for instance, aims to unpack these complexities using a combination of geo-referenced climate, population, and socioeconomic data from a variety of sources, including surveys and social media at the individual, regional, and country levels.

“Looking at how the changing climate impacts different subgroups of populations and identifying the ways in which health, mortality, fertility, and migration



“EACH DEGREE OF GLOBAL WARMING MAY LEAD TO A ROUGHLY 50% INCREASE IN THE NUMBER OF PEOPLE DISPLACED”

Reinhard Mechler

patterns are influenced, enables more realistic population projections that account for the impacts of climate change on demographic processes. This could in turn help to design policies that target vulnerable population subgroups,” Muttarak explains.

IIASA research has shown the importance of planning ahead to reduce displacement risk and preparing to help displaced people. A study published in the journal *Science*, shows how risk science can provide actionable insight into key aspects of displacement from the probability of a disaster occurring, all the way to its socioeconomic impacts and costs using upgraded displacement data. Innovative modeling can also help to address the drivers of displacement and migration through new agent-based models representing how people respond to calamities.

“Advanced disaster and climate modeling is enabling increasingly realistic assessments of risk. Knowing the

likely human and financial burdens of displacement, for instance, can inform judgements on how to reduce vulnerability, such as through better early warning and contingency planning,” says Stefan Hochrainer-Stigler, a senior researcher at IIASA.

“Changing vulnerability and exposure are major factors in future climate-related displacement risk and recent modeling suggests that each degree of global warming may lead to a roughly 50% increase in the number of people displaced if no further action is taken. Much of this displacement will happen in vulnerable communities. IIASA is working with key players in the humanitarian sector, like the Red Cross and Red Crescent movement, to guide people-centered action for avoiding and better managing displacement,” adds IIASA researcher Reinhard Mechler, who leads the IIASA Systemic Risk and Resilience Research Group.

PUT PEOPLE AT THE CENTER OF SOLUTIONS

The Earth Commission, an international group comprising renowned scientists from around the world, has outlined a challenging and fundamental core framework for a “safe and just” future for people and our planet. Put simply, ‘safe’ means not transgressing the limits of the planet’s systems, while ‘just’ implies a fair sharing of risk, responsibilities, and resources for everyone that is also in line with the aims of the UN Sustainable Development Goals (SDGs). The aim is for this framework to help quantify the conditions for the planet’s systems to avoid dangerous tipping points.

“People are central to the limits we face and the targets we hope to achieve. Our decisions are driving global change and determining our future. IIASA is supporting the Earth Commission through assessment and modeling of the safe and just development pathways for people and the planet by integrating complex interlinkages and feedbacks among Earth and human systems,” explains IIASA Emeritus Research Scholar Nebojsa Nakicenovic, who co-leads one of the commission’s working groups.

The fight against catastrophic climate change is arguably one of the most pressing challenges we are facing. To keep global warming below 1.5°C, greenhouse gas emissions should reach their peak as soon as possible and the whole world should become climate neutral by 2050. Achieving this goal will require, among other things, a full transformation of the energy sector.

Access to reliable and affordable energy services plays a crucial role in both developed and developing societies – it is integral to all sectors from medicine and education, to agriculture, infrastructure, communications, and digital-technology. Unfortunately, the burning of fossil fuels to feed our insatiable need for energy also happens to be responsible for two thirds of global greenhouse gas emissions. The urgent need to transform the energy sector to reduce its contribution to climate change is clear.

Earlier this year, the European Commission’s Group of Chief Scientific Advisors delivered a Scientific Opinion on a systemic approach to the energy transition in Europe in which they provide policy recommendations on how

the commission can contribute, accelerate, and facilitate the clean energy transition at both the European and global level.

One of the advisors' key recommendations was that a sustainable and fair transition to a climate-neutral energy system requires not only innovative technologies, but also a people-centric approach that actively involves all participants in the energy environment.

SDG7 aims to ensure access to affordable, reliable, sustainable, and modern energy for all. This goal has strong interlinkages with all other SDGs, which highlights that decisive action on sustainable energy can catalyze progress towards all the goals, including global climate protection targets. In a recent study, IIASA researchers analyzed how access to energy services may evolve over time under different scenarios of socioeconomic growth and policy scenarios that meet climate mitigation goals.

"We wanted to determine how access to energy services across households differs under different scenarios, which energy services are prioritized by households, and how climate policy scenarios may affect those choices," explains study lead author and IIASA researcher Miguel Poblete-Cazenave.

The researchers found that scenarios where ambitious climate targets are achieved do not significantly alter

access to energy services in, for instance, the Global South, as households in this region suffer from heavier affordability constraints, regardless of the effects of climate policies.

"Our results confirm that achieving climate goals is not at odds with achieving universal access to modern electricity services for populations in regions that currently lack access, but vast inequalities in electricity use will persist," notes Transformative Institutional and Social Solutions Research Group Leader, Shonali Pachauri, a study coauthor.

In a separate study, IIASA authors also showed that the amount of energy needed for decent living worldwide is less than half of the total final energy demand projected under most future pathways that keep global warming below 1.5°C.

"For most countries, especially poor countries in Africa, unprecedented growth in energy use, as well as more equitably distributed growth are essential to achieving decent living standards before mid-century," says Jarmo Kikstra, lead author of the study. "Therefore, the biggest challenge for policymakers will be to achieve an equitable distribution of energy access worldwide, which is currently still out of reach."

THE FUTURE IS IN OUR HANDS

We can still do something about climate change, but we are running out of time. With every passing year of inaction, the emissions cuts needed to limit global warming to relatively safe levels grow steeper and steeper. It is up to us. We need to secure a climate neutral future that ensures that the most vulnerable among us are shielded, and the most deprived are assured equitable access to the services many enjoy.

Further information:

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PEOPLE AT THE HEART OF CLIMATE CHANGE

WHAT IS SYSTEMS ANALYSIS?

The concept of systems analysis is difficult to pin down, but in fact, the flexible, shapeshifting nature of this discipline turns out to be its superpower.



Systems analysis is an immensely powerful way to bring scientific insights into policy, but it is not easy to define. Any brief phrase aiming to encapsulate the discipline is liable to be incomplete. So instead of a definition, here is a description, with deliberately fuzzy edges:

Systems analysis is a set of approaches for solving complex problems.

It is, of course, about systems. A system is any set of interacting components, such as species in an ecosystem or traders in a market. Even apparently simple systems with just a few components can do surprising things, as feedback loops lead to unpredictable behavior.

Many tools can be used to get to grips with the behavior of systems. They include formal ways to define and discuss problems, and an array of mathematical modeling techniques.

In applied systems analysis, the aim is not just to understand a system, but to suggest how to change it. At IIASA, systems tools are used to support decision making, bringing the insights of systems science into policy, to address the complex problems of the real world such as pollution, deprivation, and climate change.

HOLISTIC DETECTION

Systems analysis gains much of its power from recognizing that systems are not isolated. For example, the climate, the economy, and the biosphere all affect one another, forming a global system of systems.

With such a holistic view, systems analysis can tackle problems that are rooted in several different systems.



That enables it to identify:

- Trade-offs, for example between wealth and biodiversity
- Unintended consequences, such as biofuels causing carbon emissions through indirect land-use change
- Co-benefits, where one action improves two outcomes, such as electric vehicles mitigating both climate change and pollution
- Synergies, where two or more actions achieve something that no single action could accomplish

This broad and flexible perspective also helps to reveal solutions. Instead of trying to solve a problem by tinkering with one narrow system, you can take a step back and include other areas – creating a system big enough to include the solution. Treating climate change as a physical problem alone may not suggest a practical policy, but if you include economics and social sciences, you bring in the incentives and institutions that can make a difference.



MODEL ROLES

The institute's mathematical arsenal includes optimization models, agent-based models, statistical models, game-theoretic models, and many other model types used in various combinations to deal with climate, energy, and pollution; food and water; natural disasters; economy and demography.

Where several different goals compete, optimization models can help to find a balance. A highly successful example is the IIASA air pollution model, originally known as the Regional Air Pollution Information and Simulation Model (RAINS). In the 1990s, RAINS helped to guide Europe's policy on six pollutants, including particulates and sulphur dioxide (the chief cause of acid rain), calculating costs and health effects of various policies. RAINS results in Europe and India have shown the power of cooperative action on air pollution, which is much more effective than efforts by any single state, and therefore more politically attractive. Now extended to include greenhouse gases, the Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) Model reveals how clean-air policies can have co-benefits, improving the health of people and ecosystems while also curbing climate change.

The mathematics behind these models is constantly being developed to deal with new situations and complexities. New sources of data, such as crowdsourcing and novel sensors, are feeding in, and models in different areas are being linked together, to reflect real-world links between systems such as climate and the biosphere.

HUMAN VALUES

The aim of all this analysis is to steer systems in the right direction. But what is the right direction? Right for whom? On top of that, the shape of social systems is constantly changing, making them hard to navigate. To provide both a moral compass and societal map, systems analysis takes a human-centered approach, engaging with diverse viewpoints.

The soft systems methodology provides one way to do this. It is a formal process with several stages, but the essence is to bring people together to sketch out a system, identify goals and possible actions, and then model the system to find out what each action would do. That may involve a causal loop diagram, laying out how the system's components are connected to reveal critical feedbacks. The whole process is often iterative, with one round of analysis producing insights to inform the next round.

Sometimes this can lead to a consensus that satisfies everyone. It can help solutions to stick, because people that have participated in a process are much more likely to trust its outcomes and support action.

Other times, people are implacably opposed, but even then, developments in systems analysis are making progress possible. By acknowledging that even diametrically opposed worldviews can be equally valid, it can turn a stalemate into a compromise. In Nocera Inferiore in Southern Italy, conflicting views on how to deal with the risk of landslides had stymied any action. One group favored natural solutions such as tree planting; the other favored artificial barriers. From 2010 to 2013, IIASA led a participatory process with experts and participants working together to generate solutions for each opposing view, rather than imposing an expert-preferred solution. The groups eventually negotiated a mixed approach.

So systems analysis is an infinitely adaptable multi-tool, transforming to fit the particular complexity of each subject. It can shift perspectives: embracing different physical systems, disciplines, scales, and viewpoints – giving it a unique ability to grapple with the fiendishly difficult problems posed by today's fast-changing and increasingly interconnected world.

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IIASA RESEARCH HIGHLIGHTS ROLE-PLAYING SIMULATION GAMES AS A PROMISING APPROACH TO ENGAGE STAKEHOLDERS OF SUSTAINABLE DEVELOPMENT ACROSS SECTORS IN SYSTEMS THINKING AND SOCIETAL UNDERSTANDING OF ENVIRONMENTAL CHALLENGES.



For the past decade, IIASA researchers Piotr Magnuszewski and Junko Mochizuki have been reviving the long-standing IIASA tradition of creating interactive modeling games.

“What we are doing particularly differently now as compared to decades ago, is that we have a lot more opportunities to use this type of approach on the ground with policymakers and practitioners. We are using this not only as an opportunity to provide a space for non-scientists to learn about systems thinking, but also for us to learn about collective decisions and to explore ways in which we can better design models within decision- and policymaking processes,” says Mochizuki, about the water-food-energy Nexus Game.

In the Nexus Game, players take on the role of key ministers of two countries sharing the same river. After receiving a short introduction and a briefing note from

a fictitious superior, they find themselves immersed within a realistic world environment and tasked with solving a resource management problem. Every player has to make decisions that impact others and the game in direct and measurable ways.

“We are getting players in a situation where, by compressing time and space, they experience the most important system interconnections. Then they reflect on the game dynamics, but we also make a bridge to the real world situation to which they can relate,” says Magnuszewski.

Unlike many games, these social simulations have no winners or losers. Instead, the design and process developed by Mochizuki and colleagues are based on alternating active and reflexive phases that incorporate a balanced mix of actions and observations, as well as abstract concepts and concrete experiences. By applying the concepts of

HOW DO YOU BUILD A GAME?

Social learning entails that the understanding of the participant will be changed after the game, but also that the change will affect social circles and practices around the individual. In order to achieve these expected outcomes of social learning and systems thinking, the role-playing simulation game needs to follow specific design principles and processes. IIASA and the CRS have developed the Complexity-Collaboration-Sustainability simulation game design framework for social learning on complex sustainability challenges. In this framework, the first phase is devoted entirely to defining the subject of the game, including reviewing literature, consulting with experts, and narrowing down the area of interest. This crucial step is key in defining the relationship between the game design and the real world issue.

In the second phase, the environment, the roles, and their decisions are defined. This determines how the game will be played, defines the range of stakeholders in the game, and specifies what decisions are incumbent to each of them.

“One of the important concepts that we included in our framework as described in our recent paper is what is called ‘procedural rhetoric.’ Proposed by Ian Bogost, it is rhetoric in a sense of persuasive content, but achieved through design of action situations (‘procedures’) not by words. No one has to lecture you on the need to collaborate, negotiate, and compromise for a solution. When you play games, you will simply experience it and make your own sense out of it,” explains Mochizuki.



experiential learning pioneered by David Kolb, the game becomes an opportunity for each player to experience and contribute to social learning that lasts beyond the game session itself. In their feedback, participants report better understanding an overall system perspective in complex problems, a greater grasp of the importance of collaboration, including the wide network of stakeholders involved and, finally, a high level of personal engagement and fun.

The benefits of the Nexus Game have been integrated as a tool in research projects that require stakeholder engagement and collaboration. Stakeholders of the Zambezi and Indus river basins, for example, had the opportunity to play the Nexus Game as part of the Integrated Solutions for Water, Energy, and Land (ISWEL) Project. The players were able to relate the real world challenges of managing their local water, food, and energy resources to the policy exercise offered in the game. Policymakers, researchers, and students benefited from the game as an educational experience, relationship-building activity, and as a capacity building exercise, preparing the participants for the upcoming stakeholder workshops.

The Nexus Game was created in collaboration with the Centre for Systems Solutions (CRS). IIASA researchers and the CRS team have created a range of games tackling sustainability challenges, such as risk and resources management, that are all focused on the importance of systems thinking. Although more research is required to fully understand the extent of the impact of these games on policy, it appears that by walking the participants through the process of the game, researchers are able to broaden their scope of understanding. These games create a space for deliberations in which responsibilities are shared in the decision-making process, thus supporting more engaging and participatory research to policy practices.

“I think for the kind of issues that IIASA studies, ‘knowing more’ is no longer sufficient, so we are focusing on how we can facilitate more ‘doing and experimenting’ for solutions,” concludes Mochizuki.



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Regional impacts

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Improving fertilizer and water management practices in South Africa

Sustainable agriculture is a challenge for much of the world. Nowhere is this challenge more pressing than in South Africa.

In fact, growing water scarcity, coupled with rising fertilizer (Nitrogen) prices, are causing new complications for this already fraught situation. The most realistic solution to this problem is better management of both fertilizer and water usage.

A study by IIASA researchers Stephan Pietsch from the Advancing Systems Analysis Program and Juraj Balkovic from the Biodiversity and Natural Resources Program, set out to help address this problem by exploring models for potential improvements.

The researchers used a calibrated and validated Environmental Policy Integrated Climate (EPIC) model to simulate a range of Nitrogen and irrigation water levels on maize yield in South Africa's Eastern Cape. Their results show that the highest average maize yield was produced by utilizing 155 kg of nitrogen and 600 mm of water. This number represents a 69% increase over the average farmer's maize yield. The results confirm the importance of proper management practices.

"If the goal is sustainable agricultural intensification, then the solution must involve developing effective, location-specific agricultural land management strategies," explains Pietsch. "We must balance increased crop productivity with minimal negative environmental impact. The EPIC model can be used as a valuable tool in identifying optimal, site-specific irrigation water and proper application levels of Nitrogen fertilizer. This will not only increase maize crop productivity, but also maximize water use."

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Tackling solid waste management in Kenya

As in many low-income settings, the lack of proper solid waste management is a critical problem in Kisumu County, Kenya. Most of the 500 tonnes of waste that is generated here every day ends up in open dumpsites or scattered alongside roads posing an environmental and health hazard. Open burning of the waste is common, releasing toxic air pollutants that cause respiratory and cardiovascular diseases.

With urbanization, growing population, and projected economic growth, this issue is likely to worsen in the coming years. To avert the looming waste crisis, IIASA researchers Adriana Gómez-Sanabria and Gregor Kiesewetter participated in a study analyzing different waste management scenarios as part of a multi-partner effort to reduce air-pollution in Kisumu.

Using a systems-dynamics approach, they modeled how the amount of waste, greenhouse gas, PM_{2.5} (fine particulate matter) emissions, and the number of life years saved changed based on two different waste management interventions: converting solid waste into biogas and banning open burning in landfills. The researchers found that combining the two interventions would save over 1.1 million tonnes of CO₂ emissions, 1,150 cumulative life years, and reduce air pollution compared to baseline projections by 2035.

"Waste is not just waste, it is also a material — by turning it into clean fuel we not only improve waste management, but also reduce greenhouse gas emissions and improve air quality," says Gomez Sanabria.

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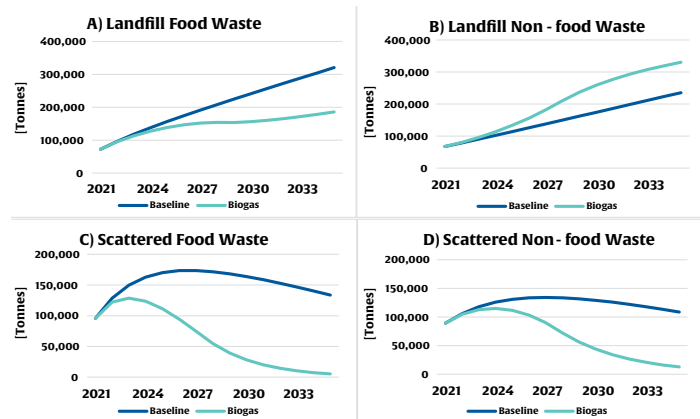


Figure: Stocks of waste, Baseline vs. Biogas scenario.



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Assessing the cost of a herd immunity approach to COVID-19 in the USA

While there is mounting evidence on the large economic cost of policy interventions aimed at containing the progression of COVID-19, little is known about the cost of inaction, which is tantamount to a strategy that seeks to reach herd immunity through infection.

In their study, IIASA Economic Frontiers Program Director Michael Kuhn and his coauthors assessed the economic burden that such an approach would have imposed on the United States. The study shows that a lack of behavioral or policy responses to COVID-19 would have cost the USA's GDP as much as US \$1.4 trillion by 2030. Furthermore, when accounting for the value of lives lost, the total economic burden in that time could have reached as high as \$94 trillion.

"Our study provides an estimate of the minimum economic cost of COVID-19 (the cost faced through loss in labor due to morbidity and mortality, and through loss in capital investments due to treatment costs) calculated for the case that there are no private or public measures limiting the spread of the disease," explains Kuhn. "If you add to this the value of lives lost, the cost becomes staggering. All of this should be further proof that large-scale investments into the development of vaccines and the resilience of health care systems to cope with pandemic crises yield huge returns for all of us."

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The pursuit of wind power expansion in Brazil

As more countries try to reach net carbon neutrality, the use of renewable energies like wind power have also increased. Brazil has seen a ten-fold increase in wind power capacity in the last decade, and plans to double that by 2029.

Although wind power has a relatively small carbon footprint, its infrastructure expansion has significant land-use impacts. IIASA researcher Aline Soterroni contributed to a study that explored the land-use impacts of Brazil's wind power development in the past and possibilities for reducing environmental risks from future wind power expansion.

Currently, most of Brazil's onshore wind parks are concentrated in ecosystems prone to degradation, desertification, and species extinction such as an understudied Brazilian ecoregion known as the Caatinga.

"The Caatinga biome in Brazil is the largest and most diverse dry forest of the Americas. Most current and planned wind farms are in this biome, which greatly overlaps with biodiversity priority areas," explains Soterroni.

The study shows that future wind power deployment can be fully integrated with human-altered lands. Resources for this are available and would reduce further impacts in vulnerable areas.

"In Brazil, wind parks are sometimes a sensitive subject as land owners have historically not been properly compensated for the use of their land. This makes the issue a bit more complicated. Further research may be needed to consider the tradeoffs between clean energy, biodiversity preservation, and socioeconomic goals," concludes lead researcher Olga Turkovska from the University of Natural Resources and Life Sciences (BOKU), Vienna.

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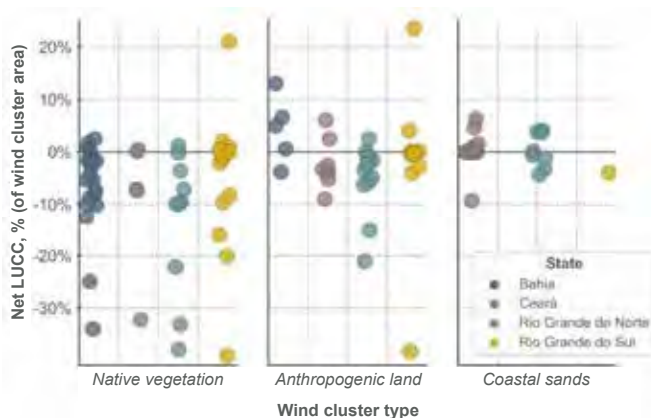


Figure: Difference in net land-use and land cover change (LUC) among wind cluster types. The X-axis shows the type of the wind cluster. The Y-axis refers to net LUC relative to the wind cluster area (%). Each circle corresponds to one wind cluster and its color refers to the federal state where the cluster is located. Positive values indicate native vegetation regrowth.

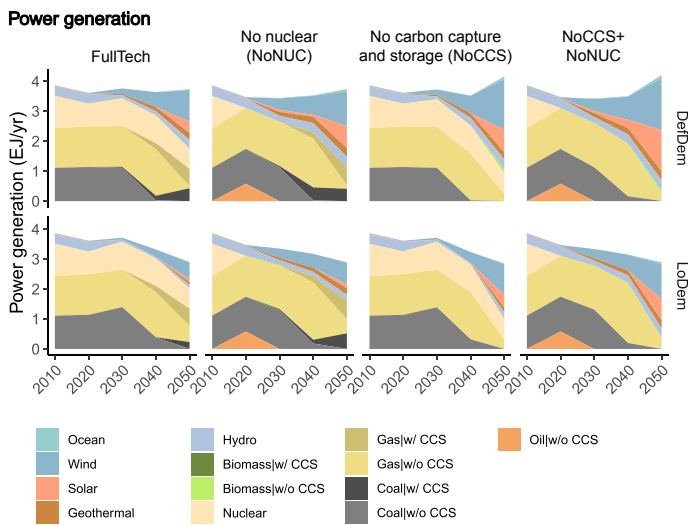


Figure: Comparison of power generation between the DefDem and LoDem MCS scenarios.

Using energy demand reduction for decarbonization in Japan

Like much of the world, Japan has put in place a strategy to reduce its carbon footprint in the coming decades.

Specifically, Japan has vowed to reduce greenhouse gas emissions by 80% before 2050. Its success will depend largely on the concept of energy demand reduction, with particular focus on reductions around energy services such as behavioral changes and material use efficiency improvements. However, the potential results of these changes have not been sufficiently evaluated.

A study by IIASA researcher Shinichiro Fujimori and his colleagues used a detailed, bottom-up energy system model, combined with an energy service demand model, to explore potential energy system changes and their respective cost implications.

Their results show that Japan's energy demand in 2050 can be cut by as much as 37% using these measures. The country's current plan relies heavily on technology, such as carbon capture and storage (CCS) solutions. The findings of the study emphasize the importance of implementing energy service demand reduction measures along with technological solutions.

"To develop a carbon neutral energy system, energy supply sources need to completely change," explains Fujimori. "Energy demand reduction can facilitate this major system change. In fact, energy demand reduction offers numerous benefits to the prospect of climate change mitigation in Japan. Additionally, lowering energy demand would have a much greater impact if some key technologies, such as CCS are unavailable."

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An analysis of forest management in the Republic of Korea

Biodiversity loss has long been one of the most devastating consequences from land-use change due to human activities like urban and agricultural expansion, industry, and deforestation, and it has only been exacerbated by the effects of climate change. Remarkably, the Republic of Korea is a country that has managed to achieve rapid economic development while maintaining its biodiversity since initial reforestation efforts began after the Korean War. Although urban hubs like Seoul and Busan played a part in forest decline, overall, the quality of these forests has improved due to excellent continuous forest management.

IIASA researcher Florian Kraxner contributed to research analyzing the biodiversity persistence of plants in the Republic of Korea since the 1960s. National data sets were used to create spatial scenarios of past versus present land use and habitat quality. Additionally, researchers constructed future scenarios evaluating biodiversity persistence and the net effects of forest management on biodiversity.

The resulting scenarios displayed positive biodiversity persistence over the years, with the Korean government managing to offset the negative effects of urbanization through reforestation and habitat management efforts. The study also showed that the most serious consequences of climate change could be mitigated but that change is needed, as current management practices are not enough. Further research with more diverse future land-cover and land-use scenarios that would allow Korea to better prepare for a worst-case scenario was also recommended.

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Supporting sustainable reindeer management in Finland

Reindeer husbandry is a traditional livelihood for many indigenous Saami and Finnish people in northern Finland, where it provides a vast array of social, cultural, and economic benefits. The modern-day pressures of climate change, economic development, and competing forms of land-use, however, are posing challenges to the integrity of the reindeer management system.

There are various public authorities that steer reindeer management through the changing times. Even though reindeer herders are the central actors in the system, they are often not able to influence the policies pertaining to their livelihood. To help manage future environmental conflicts, in a recent IIASA collaboration, researchers surveyed how herders perceive the drivers of change in reindeer management, along with how these perceptions vary with the diverse land-use and climate patterns found in different herding regions.

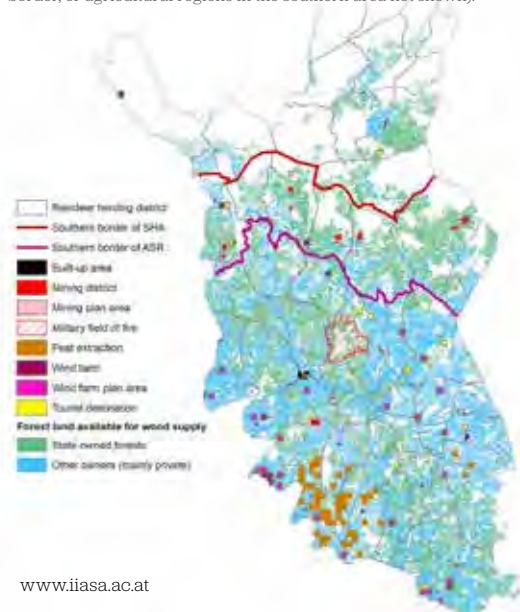
The crucial factors for most herders were those that directly affected the welfare of reindeer and calving success, such as the amount of ice on pastures or the presence of other land-use forms that influence reindeer foraging and the daily work of herders due to the fragmentation of pastures. Herders had varying or polarized opinions on other factors, showcasing the regional differences in reindeer management.

“Awareness of reindeer management is low on the governance level. With this study we hope that local voices will be better heard and included in future policy decisions,” says Mia Landauer, a researcher at IIASA and the Arctic Centre at the University of Lapland.

By **Fanni-Daniela Szakal** Further info: pure.iiasa.ac.at/17311

Mia Landauer: landauem@iiasa.ac.at

Figure: State and privately owned land used for forestry and the present and planned land-use projects in the reindeer management area (RMA; regions with high predator density in the northern area and close to the eastern border, or agricultural regions in the southern area not shown).



Analyzing the dynamics of fisheries in the Baltic Sea

As the global population continues to surge, one of the most complicated challenges facing humanity is securing sustainable food sources.

Fisheries not only reduce the abundance of large piscivores such as cod, pollock, and tuna in ecosystems across the world, but also target smaller species like herring, capelin, and sprat that make up piscivores' diets.

A study by Mikko Heino and Ulf Dieckmann, both researchers in the IIASA Advancing Systems Analysis Program, and their colleagues, used a community-dynamics model to explore the effects of harvesting forage fish.

Unlike single-species models often used for fisheries assessments, their study accounts for important factors such as individual-level bioenergetics and size structure.

On this basis, the researchers have extended and analyzed a dynamic bioenergetic model of the Baltic Sea, in conjunction with historical pattern analysis, to test the effects of fishing for both piscivores and their forage fish. Their findings suggest that piscivores benefit from forage-fish harvesting when the fishing pressure on piscivores is high.

“It is true that we must avoid the overfishing of forage fish,” explain Heino and Dieckmann. “However, our findings show that reducing fishing pressures on forage fish may have unwanted negative side effects on piscivores. In fact, decreasing forage-fish exploitation could lead to declines, or even collapses, of piscivore stocks. We must keep this in mind as we manage the exploitation of fish stocks around the globe.”

By **Jeremy Summers** Further info: pure.iiasa.ac.at/17024

Mikko Heino: heino@iiasa.ac.at

Ulf Dieckmann: dieckmann@iiasa.ac.at

Jim Hall, Chair of the IIASA Science Advisory Committee, writes about how new data sets, systems analysis, and machine learning can help pinpoint hotspots of vulnerability and target measures to enhance resilience to future threats from climate change.



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Shedding light on systemic risks from infrastructure failure

When natural disaster strikes infrastructure that delivers energy and water services or enable transport and digital communication, the consequences can be devastating far beyond the immediate destruction. So how can we reduce the risks of infrastructure failure cascading through economies and societies? Systems analysis and machine learning are revealing new ways to minimize the systemic risks.

The provision of new infrastructure can lock in patterns of development for years to come. Energy and transport systems have locked-in carbon-intensive behaviors and economic activities. Infrastructure decisions also lock in exposure to climate-related extremes. An analysis of all of the world's land transport networks that my team did with the World Bank, found that 23% of roads and railways are exposed to climate-related hazards.

The consequences of climate-related shocks to infrastructure networks extend far beyond the direct costs of asset repair and reconstruction. Without transport connectivity, for instance, people can't travel for work or access services like healthcare, and trade in essential commodities is disrupted. Billions of dollars of trade are at risk every year from climate related disruptions to roads, railways, airports, and ports.

Until recently, the vulnerability of infrastructure networks to climatic extremes was mostly only studied at local and national scales. Some studies, including at IIASA, have looked at particular categories of global infrastructure exposure, like the risk of droughts to hydropower production, and cooling water shortages to thermo-electric power plants. Now,

thanks to newly available big datasets and machine learning techniques, we are rapidly piecing together a complete picture of interdependent infrastructure networks covering energy, transport, water, and digital communications. This network analysis can be intersected with globally available datasets on climatic extremes and projections of how these threats may become more severe in the future. High-resolution spatial demographic and economic datasets are helping to quantify the consequences of failure, while new satellites are allowing us to observe the impacts of climatic extremes as they occur.

By analyzing the exposure of infrastructure networks to climatic extremes, their vulnerability to damage and disruption, the duration of disruption, and the pace of recovery, we are able to construct a picture of the resilience of infrastructure systems worldwide. This can help us to pinpoint hotspots of vulnerability and target measures to enhance resilience to future threats. That could include nature-based solutions like mangrove restoration, as well as physically strengthening assets to cope with more extreme events. Diversification and increasing stocks of commodities can make supply chains less fragile. Disaster risk finance can help governments to quickly access the resources they need to repair and recover. Knowledge from systems analysis is helping to test and implement these solutions.

Further info: Koks, E.E., Rozenberg, J., Zorn, C., Tariverdi, M., Vousedoukas, M., Fraser, S.A., Hall, J.W., Hallegatte, S. (2019). A global multi-hazard risk analysis of road and railway infrastructure assets. *Nature Communications*, 10(1): 2677. DOI: 10.1038/s41467-019-10442-3.

Jim Hall: jim.hall@eci.ox.ac.uk

Interview

By Jeremy Summers

Q&A with Roula Inglesi-Lotz, Professor of Economics at the University of Pretoria, South Africa, and member of the Global Young Academy (GYA).

Developing and connecting the next generation of researchers

IIASA collaborates with the Global Young Academy (GYA), which develops, connects, and mobilizes young research talent from around the world. The GYA gives young scientists a voice in the global scientific community and empowers them to make evidence-based and inclusive decisions, and lead international, interdisciplinary, and inter-generational collaboration.

Q. What first attracted you to the GYA and what have been some of the biggest takeaways from your involvement?

A. When I first learned of the GYA, I was attracted to its focus on a multicultural and multidisciplinary perspective. The GYA provides young scientists with a platform to express their voice, and so much more: a place to engage with other scientists from all over the world and gain exposure to unfamiliar backgrounds and scientific systems. In my second year, I served as co-lead of the Women in Science Working Group. The discussions, outreach, and outcomes of this group taught me a lot about the global conditions of women in science, including their aspirations and challenges. It was eye opening to see how similar we all are and how women are striving to make an impact on current and future generations of women in science. I am sincerely inspired by all of them.

Q. Why is collaboration so important across international, disciplinary, generational, and other boundaries?

A. Collaboration across all kinds of boundaries has become the norm in recent times. Scientists worldwide have demonstrated the benefits of international collaboration during the pandemic with

the development of vaccines and examination of the virus. Ensuring gender and generational inclusivity, not only in the working environment but also in decision-making processes, helps to achieve goals that are more inclusive and multi-perspective. Young scientists are often excluded from science decision-making even though senior academics and researchers admit that early-career researchers bring fresh perspectives and informed, modern, and relevant expertise from the point of view of scientific knowledge and science leadership. Promoting, supporting, and including early career researchers will not only have direct effects on the current generation of scientists, but also multiplier effects on the next generation.

Q. What outcomes do you hope to see in your time with the GYA?

A. The GYA demonstrates how diversity in our membership ensures that everyone brings something to the table. However, there is still work to be done. GYA has a number of important projects in the pipeline. One example is the Global State of Young Scientists (GloSYS), which will empower higher education stakeholders to make a difference and ensure a conducive environment for young scholars in Africa. I am also very enthusiastic about the GYA's involvement at the organization of the World Science Forum 2022, an international conference dedicated to current global issues and future priorities for promoting cross-disciplinary and innovative work and collaborations.





Message from the director

“ IIASA is approaching its 50th year with optimism. With COVID-19 vaccinations on the rise, researchers and staff are cautiously being welcomed back to their offices in Laxenburg.

Over the past 50 years, IIASA has been able to promote multilateralism and research cooperation among countries, and has been facilitating science diplomacy efforts since the Cold War up until the current COVID-19 pandemic. As part of its 50th anniversary celebrations, IIASA plans to organize a series of events throughout 2022 to highlight the institute’s achievements over the last half-century and the value of systems analysis in helping to address issues of global and universal concern. Plans are underway for international science conferences promoting global sustainability, and celebrations at the Schloss Park in Laxenburg.

This was a big year for global climate research and headlines were generated by the Intergovernmental Panel on Climate Change (IPCC)’s sixth assessment report. As with previous reports, IIASA researchers provided valuable contributions. Research into the multiple aspects of climate change is a large part of the institute’s portfolio, as this issue of *Options* shows, and our researchers also provided highly relevant and timely inputs to this year’s United Nations Climate Change Conference, COP26, in Glasgow, UK.

Over the past 50 years, IIASA has been able to provide research leadership and the tools to make a difference through science. None of the institute’s accomplishments would however have been possible without the wonderful IIASA staff, alumni, and local supporters. I thank all of you for your continued dedication and commitment.

ALBERT VAN JAARVELD

By Rachel Potter

The Laxenburg Environment and Climate Day



This year’s Laxenburg Environment and Climate Day organized by the municipality of Laxenburg, brought together local residents and regional stakeholders to discuss environmental topics and exchange information. As a “Climate Alliance” community in Austria, the municipality is committed to raising awareness about climate issues.

IIASA has regularly co-hosted this annual event in the past and again participated in this year’s outdoor event, which included a local tour to the Franz-Joseph-Park and the Rolling Hills — a local restoration site returned to nature over 10 years ago and now home to a number of species specific to the region.

IIASA researcher Martin Jung introduced visitors to a biodiversity app, enabling them to identify and record the presence of multiple plant and insect species. He also gave a short presentation overview of why biodiversity is important, how our scientific understanding of conservation biology has changed over the last decades, and how IIASA research addresses key questions of societal relevance such as how much biodiversity has declined in the last decades and on the policy option space for interventions.

“Despite most of our work addressing issues of global relevance and engaging in science-diplomacy between countries, it is important to listen and interact with local communities to understand how issues such as climate change or biodiversity loss are perceived. It also highlights to the local community the significance of the institute’s work and highlights its reputation in the scientific and policy world,” says Jung.

Further info: www.iiasa.ac.at/events/21-Laxenburg

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Keywan Riahi
Energy, Climate,
and Environment
Program Director



Petr Havlik
Integrated Biosphere
Futures Research
Group Leader



Michael Obersteiner
senior researcher in the
Exploratory Modeling of
Human-Natural Systems
Research Group



Joeri Rogelj
senior researcher in the
Integrated Assessment
and Climate Change
Research Group



Volker Krey
Integrated Assessment
and Climate Change
Research Group
Leader



Zbigniew Klimont
Pollution Management
Research Group
Leader



Yoshihide Wada
Biodiversity and
Natural Resources
Program Director



Pavel Kabat
former IIASA
Director General



Wilfried Winiwarter
senior researcher
in the Pollution
Management
Research Group

IIASA researchers top the Reuters Hot List of climate scientists

Nine IIASA researchers made it onto the Reuters Hot List – the media giant’s ranking of the world’s most influential climate scientists – with IIASA Energy, Climate, and Environment Program Director, Keywan Riahi, claiming the top spot.

The Reuters Hot List of climate scientists identifies the world’s 1,000 most influential scientists, using a combination of three rankings. These are based on the number of papers a scientist has published on topics related to climate change; how often those papers are cited by other scientists in similar fields of study; and how often those papers are referenced on other channels including the press, social media, and policy papers.

Topping the list in the number one position is IIASA Energy, Climate, and Environment Program Director, Keywan Riahi, followed by Integrated Biosphere Futures Research Group Leader, Petr Havlik in position number six. Other IIASA researchers on the list are: Michael Obersteiner, senior researcher in the Exploratory Modeling of Human-Natural Systems Research Group and Director of the Environmental Change Institute at Oxford University; Joeri Rogelj, senior researcher in the Integrated Assessment and Climate Change Research Group and the Transformative Institutional and Social Solutions Research Group; Volker Krey, Integrated Assessment and Climate Change Research Group leader; Zbigniew Klimont, Pollution Management Research Group leader; Yoshihide Wada, Biodiversity and Natural Resources Program director; Pavel Kabat, former IIASA Director General and CEO; and Wilfried Winiwarter,

senior researcher in the Pollution Management Research Group.

Riahi credits his position on the ranking to the institute’s openness when it comes to sharing data and models with other scientists, saying that this creates long-standing collaborations and helps to share innovative approaches and techniques that are important for the global scientific community.

“Unlike other institutions, the work is not complete at IIASA when the research is done. For us it is important that our knowledge is shared and made accessible to other researchers, particularly those in countries where IIASA have National Member Organizations,” he says.

“Our aim is to be at the interface between science and policy, where real world problems are driving the research and not the other way round. These novel Reuters metrics confirm that our work is being read and contributing to the climate debate beyond academia,” adds Havlik.

IIASA is extremely proud that its researchers are among those represented on the list by Reuters and sees this as confirmation that the institute’s work is contributing to addressing the global threat posed by climate change.

Further info: www.iiasa.ac.at/news/21-reuters



Vienna Energy Forum conference

SUSTAINABLE ENERGY: WHERE ACTION MEETS AMBITION

Against a background of widespread, rapid, and intensifying climate change impacts and the COVID-19 pandemic, the Vienna Energy Forum (VEF) 2021, guided by the theme “Where Action Meets Ambition”, was held for the first time in a fully virtual format with an agenda to spur action.

Founded in 2008 by a joint initiative of IIASA, the Austrian Government, and the United Nations Industrial Development Organization, VEF 2021 brought together thinkers and practitioners from across the world to explore key issues relating to advancing the sustainable development of energy.

IIASA Deputy Director for Science, Leena Srivastava, spoke at the opening session while IIASA researcher Shonali Pachauri was a panelist at the first-ever Youth Forum (Youth for VEF). This was hosted in partnership with the SDG7 Youth Constituency and co-created with inputs from young researchers, professionals, entrepreneurs, activists, and other young people in the sustainable energy sector.

IIASA was well-represented by researchers from the Energy, Climate, and Environment Program including Keywan Riahi, Bas van Ruijven, and Elina Brutschin – who presented at several side events covering a range of topics. These included: looking at a new generation of global transformation pathways, which explore strategies to limit temperature overshoot without relying on net negative emissions (part of a major community effort: ENGAGE); developing methods and standards for climate stress testing the financial sector to minimize the risks of climate change and climate policy on financial assets and productivity (part of a partnership with the Network for Greening the Financial System); and exploring possible pathways for decarbonizing industry (organized by the Indian Institute of Technology, Bombay).

A multimedia exhibition booth featured interactive presentations covering a range of IIASA research topics relating to sustainable energy and forging an inclusive pathway that leaves no one behind on the road to net-zero emissions by 2050.

Further info: www.iiasa.ac.at/events/21-VEF

KEYWAN RIAHI APPOINTED TO NEW UN TEN-MEMBER GROUP OF EXPERTS

IIASA Energy, Climate, and Environment Program Director, Keywan Riahi has been appointed by UN Secretary-General, António Guterres, to serve on a special advisory group that will support the Technology Facilitation Mechanism, a key part of the post-2015 architecture for the implementation of the Sustainable Development Goals (SDGs). The new ten-member group will advise on ways of harnessing science, frontier technologies, and innovation to accelerate progress on the SDGs. They are internationally recognized in their respective areas of work and bring diverse expertise and experience across disciplines on science, technology, innovation, and entrepreneurship.

www.iiasa.ac.at/news/21-Riahi

COMPLEXITY IN MACROECONOMICS AWARD FOR SEBASTIAN POLEDNA

IIASA Acting Research Group Leader Sebastian Poledna has won a research paper competition on the subject of complexity and macroeconomics organized by the Rebuilding Macroeconomics (RM) Network. In the awarded paper, Poledna and his colleagues designed and implemented a new prototype of an economic agent-based model (ABM) that is suitable for economic forecasting and evaluating policy measures. The network is funded by the Economic and Social Research Council (ESRC) in the UK, and hosted by the National Institute of Economic and Social Research (NIESR), which is the oldest independent economic research institute in the UK.

www.iiasa.ac.at/news/21-Poledna



Jessica Jewell

Jessica Jewell's research focuses on identifying feasible solutions to energy and climate challenges. She is currently an associate professor in energy transitions at the Department of Space, Earth, and Environment at Chalmers University of Technology, Sweden, professor at the Center for Climate and Energy Transitions at the University of Bergen, Norway, and IIASA guest researcher in the Advancing Systems Analysis Program.

She recently started a European Research Council (ERC) Starting Grant project called MANIFEST. While we know how to solve climate change in mathematical models, she's trying to figure out which solutions would work in the real world. Answering this question is challenging scientifically because the climate problem requires unprecedented action and there are no direct historical analogues. She overcomes this by

unpacking the mechanisms that have shaped similar actions in the past. By understanding these mechanisms she hopes to be able to anticipate what is and is not possible in the future.

Before taking up her current position, Jewell worked at IIASA from 2011–2019 after participating in the Young Scientists Summer Program (YSSP) in 2010. She was initially attracted to IIASA because she wanted to understand the large-scale mathematical models, which are at the heart of a lot of the Intergovernmental Panel on Climate Change (IPCC)'s analyses in formulating pathways to reach climate targets. While working at IIASA, she maintained a firm footing in empirical research – as opposed to large-scale modeling – and developed expertise in bridging future visions of sustainable worlds with today's hard realities.

Today, she co-leads the POLET research group – a multi-institutional and interdisciplinary research group with two post-docs and seven PhD students. Since joining Chalmers University, supervising PhD students has quickly become one of the favorite parts of her job. She loves discovering new things with her students and mentoring them to achieve their goals.

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By **Monika Bauer**

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People profiles

Achieving sustainable development with better data

Dilek Fraisl researches how citizen science can provide data needed to monitor progress on the UN Sustainable Goals (SDGs).

Fraisl's interest in alternative data sources developed after joining IIASA in March 2016 as a researcher working with citizen science. Previously, her research was around sustainability issues and she was aware that many countries, particularly developing countries, struggle to put together the data needed to measure progress towards sustainable development.

Identifying how alternative data sources like citizen science can bridge these gaps and applying these approaches to complement official statistics and monitor the SDGs, has been the focus of her research at IIASA.

"Our research has shown that citizen science has the potential to contribute to all 17 SDGs and that around 33% of the SDG indicators could be supported through citizen science initiatives. These findings have generated a lot of interest among policy- and decision makers responsible for developing and implementing the global indicator framework for the SDGs and their targets," she explains.

To facilitate the use of citizen science in the implementation and monitoring of the SDGs, Fraisl has been part of efforts to establish a network-of-networks aimed at offering a coordinated point of entry for governments and business partners seeking to collaborate with the global citizen science community. "We have been working with the global citizen science community to establish the Global Citizen Science Partnership, which is hosted at IIASA. Through this initiative, we will be able to provide tools, procedures, guidelines, and data for citizen science to facilitate effective engagement with the SDGs," she adds.

By **Rachel Potter** **Dilek Fraisl:** fraisl@iiasa.ac.at



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Thinking about policies for just transitions

Kian Mintz-Woo participated in the IIASA Young Scientists Summer Program (YSSP) in 2018 and is currently a guest researcher in the Equity and Justice Research Group of the Population and Just Societies Program. He is also a permanent lecturer at University College Cork in Ireland.

Mintz-Woo researches how to think about policies for just transitions. Mitigating climate change involves large changes in society, but it is important to think through how these changes can occur while respecting both procedural and distributive justice.

"We have to respect the views of different groups in society, including marginalized people, as well as consider the outcomes for those who have most to lose. This builds on work I did on pricing in the benefits and burdens of climate change. Although the costs of climate change are large, some regions and professions may benefit," he explains.

Mintz-Woo has been engaging with the public through interviews for newspapers on the most recent report by the Intergovernmental Panel on Climate Change (IPCC). He has also coauthored an opinion about carbon taxes, and written short essays for the Irish national broadcaster RTE (including a video interview).

He states, "I think public engagement is important for two reasons. First, many people are concerned about climate change, but few people *talk* about climate change. By bringing it more into the public domain, we can recognize that we care about it. Second, I think it is important that we communicate science to the public to demonstrate the relevance and value of science."

By **Monika Bauer** **Kian Mintz-Woo:** mintzwoo@iiasa.ac.at



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Q&A

Advancing equitable transitions to net zero

Caroline Zimm joined IIASA in 2014 and is leading the IIASA Strategic Initiative Program's Just Transitions to Net-zero Carbon Emissions for All (JustTrans4ALL) project.

Q What are your key research interests and how did they evolve?

A Before joining IIASA, I worked in development cooperation and project development for rural energy access and renewable energies in the Global South. I came to realize that our activities were based on what we had done before, but were not necessarily following the latest science or most effective practices. It made me want to better understand how human behavior, technologies, and policies interact and how they can be harnessed to improve livelihoods and sustainable human development.

I wanted to know: Why do some technologies get adopted faster and more widely? How can we accelerate the uptake of technology? Why do some countries introduce certain policies and not others? Some of the development projects I worked on were financed through carbon credits, which brought me closer to climate policy and finance, and related issues such as historic responsibility and climate justice. More recently, I have become interested in looking at the outcomes and effectiveness of such policies.

Q What does the JustTrans4ALL project aim to do?

A In JustTrans4ALL, we will develop scenarios that stay within the Paris Agreement temperature target while overcoming a range of deprivations faced by people experiencing poverty, such as poor health access and nutrition, lack of educational opportunities, and inadequate amenities. Providing everyone with basic living standards as agreed by all nations in the UN Sustainable Development Goals should be the first step. This is currently not widely reflected in climate mitigation scenarios that are used in climate research and to inform policymaking. We plan to base these scenarios on new insights into synergies between energy, education, health, and climate mitigation capacity.

Q How does your work with the Earth Commission inform the fight against climate change?

A My work with the Earth Commission aims to identify a safe and just corridor for humanity and the planet. The Paris Agreement temperature guardrail of 'well-below' 2°C acts as an example. We identify risk thresholds, pinpoint interactions with other systems, and ascertain how tipping elements might reduce our wiggle room – for climate, the biosphere, etc. By defining a safe and just development corridor, we hope to support policymakers and companies to anchor their decisions in science. We consider thresholds and ranges for access to crucial services and nature's contributions to people as well as levels of acceptable harm related to Earth System impacts.

Q What do you enjoy most about working at IIASA?

A I enjoy the international and interdisciplinary atmosphere: my background is quite diverse, covering different fields of study such as economics and environmental management, political science, and a bit of engineering. I have never felt strongly at home in one discipline or approach, but rather have always tried to focus on the research question. Interdisciplinary or post-disciplinary science, something that IIASA has long lived and pioneered, can provide answers to many of today's challenges.

By Rachel Potter Caroline Zimm: zimmc@iiasa.ac.at

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Christine Hung, YSSP participant

“IIASA has a great reputation as a research institute – the guidance I’ve received from scientists at the insitute with their experience and background, has been invaluable.”



Roope Kaaronen, YSSP participant

“During the YSSP I met so many talented and friendly researchers from such diverse scientific and cultural backgrounds. I feel like my time at IIASA will result in many future collaborations!”

DEADLINE: 14 January 2022

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