International Institute for
Applied Systems Analysis
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ANNUAL REPORT 2016

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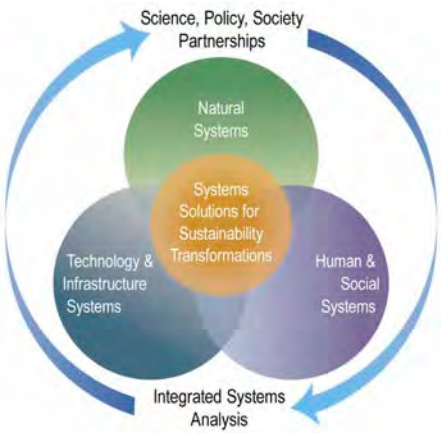
Contents

Welcome from the Director General and CEO

The IIASA mission is to provide insight and guidance to policymakers worldwide by finding solutions to global and universal problems through applied systems analysis in order to improve human and social wellbeing and to protect the environment.



The year 2016 saw IIASA embark on the new Research Plan 2016–2020, guiding the institute towards a productive and successful future.

IIASA research continued to advance systems analysis and support policy around the world. To name just a very few highlights: at a global level, IIASA researchers assessed countries' climate pledges, showing that they currently fall significantly short of meeting the goals in the Paris Agreement. At the regional level, input from IIASA provided an important basis to the revised EU Renewable Energy Directive. At a national level, the institute has developed a blue-print for managing air pollution in fast-growing megacities in developing countries and provided a scientific basis for energy planning in Indonesia. These, and many more highlights from across IIASA are covered in our latest Annual Report.

IIASA continues to foster connections with researchers, policymakers, and business leaders worldwide. In 2016, 348 researchers from 50 countries worked at IIASA, 2,299 collaborators visited the institute, and around 25% of alumni were actively involved in its work. Together, they made up a global network of over 3,500 scholars.

There were 615 IIASA publications in 2016, of which 406 were peer-reviewed journal articles, written in collaboration with over 1,500 coauthors from 159 institutions in 50 countries. IIASA also started an advanced open access policy, and by the end of 2016, 71% of its peer-reviewed articles were made freely accessible via the IIASA repository, which stores a total of 14,054 publications.

The institute's annual budget in 2016 was €22 million, of which 56% was from prestigious research funding agencies in 24 countries spanning Africa, the Americas, Asia, Europe, and Oceania. These diverse sources of income enable IIASA to perform research that is truly independent, and we take this opportunity to thank our National Member Organizations for their support in 2016.

Human capital is the biggest asset of IIASA and in 2016 we gave human capital management the highest priority, with the aim of keeping IIASA an attractive and competitive place for international researchers to come and work. At the same time, the institute fosters an environment with the key values of diversity, equity, and overall wellbeing. To that end, we worked to repair the initial gaps identified in an inclusive process involving all staff.

In 2016, the IIASA Council launched a comprehensive, independent, international review, which will critically assess and advise all IIASA structures on how to make the institute even more robust in responding to its current growth and to the challenges of the future. We expect the review panel to report to the Council in 2017 and the next Annual Report will cover both the recommendations and our response.

Over and above these member country contributions, additional competitive funding totaled €45 million between 2010 and 2016. This is part of a funding portfolio of €360 million — the total awarded to external partner and consortia projects featuring collaborations with IIASA. We are especially proud of our nine European Research Council grants.

Finally, IIASA would not be where it is today without the invaluable contributions of staff and collaborators. I would like to thank them wholeheartedly for their tireless efforts, and look forward to even greater success in 2017.

Pavel Kabat
Director General and CEO, IIASA

The first five years under the IIASA 2011-2020 Strategic Plan had substantial impact, shaping policy at national, regional, and global scales. The Research Plan 2016-2020 builds on this success and proves the foundation for the institutes research direction and the necessary flexibility to accommodate changing scientific or policy priorities.

The Research Plan 2016-2020 moves away from the idea that problems (such as climate change) are separate from drivers (such as population growth). Problems, drivers, and impacts are in fact closely related elements of the planetary system and should be considered holistically.

To this end, the Research Plan has an enhanced emphasis on cross-cutting research, a focus on future initiatives, as well as large-scale, integrated "nexus" projects.

More on IIASA research

Leadership in applied systems analysis

Systems analysis is one of the few tools that has the breadth and depth to find long-lasting solutions to the complex, interconnected challenges we face today.

Selected highlights

Wildfires of the future

Using game theory to understand cooperation

Modeling global water use for the 21st century

Modeling love: Understanding the dynamics of human relationships

Untangling uncertainty for disaster risk projections

Getting the non-CO2 greenhouse gases right

Shared Socioeconomic Pathways: Finding routes to sustainability

Negative emissions in the tropics

Sustainable fisheries management

Harnessing the power of citizen science

Reaping the co-benefits of air pollution and climate policies

Supporting sustainable water policy

Disaster forensics: Detecting best practice

Measuring water security with hydro-economic classification

Sustainable transport through agent-based modeling

Food security in a changing world

Sustainable consumption and economic growth

Adopting sustainable technologies: New methods for a new world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Wildfires of the future

Wildfires have devastating effects across the globe, and as countries struggle to deal with their increased frequency under climate change, predicting their future impacts is crucial. To do this, researchers from the Tropical Futures Initiative adapted the IIASA wildfire model to Indonesia, adding the effect of burning peat and incorporating crowdsourced data on human activity.

Wildfires not only damage property and cause substantial air pollution, they also endanger lives and livelihoods. In Indonesia, fires affect millions of hectares of land, producing severe smoke haze pollution, and leading to CO_2 emissions comparable to the annual fossil fuel emissions of India.

Assessing the area of land burned is an important step in estimating the cost of wildfires to society, their effect on air quality, and the CO_2 emissions they might cause. The IIASA wildfire climate impacts and adaptation model (FLAM) has been developed to project future burned areas and to assess climate change impacts and adaptation options.

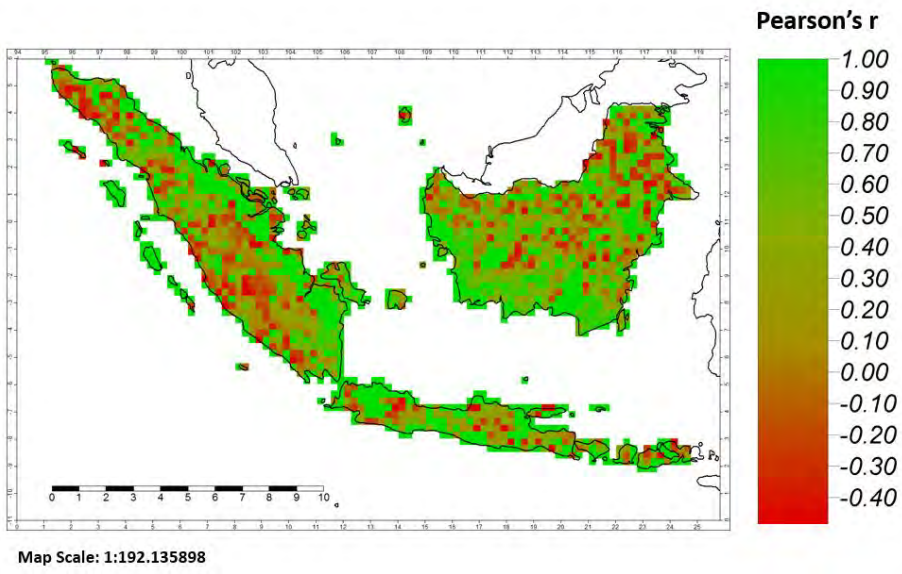
To do this, the model combines key information on climate, human activity, and fuel moisture and availability.

FLAM has previously been used to explore wildfires in Europe, and has performed well when compared with real historical data [1][2]. In the latest study, along with adapting the model for Indonesia, the researchers upgraded the model in several ways [3].

First, they included the impacts of burning peat as well as forests. Peatlands act as globally important carbon storage, and including them is crucial to understanding the true impacts of wildfires.

Second, the team developed a new approach for determining the probability that a fire would start.

Finally, the team improved the model's representation of human activity—which substantially increases the chances of wildfires—by using maps developed at IIASA based on data generated by citizen scientists searching satellite images for signs of human activity. When tested against real data collected in 2000-2008, the model showed satisfactory accuracy.



Spatial correlation between the FLAM model projections of yearly burned areas for the forest fires and real-world data for the period 2000-2008.

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Tropical Futures Initiative

Further information

The project *Delivering Incentives to End Deforestation: Global Ambition, Private/Public Finance, and Zero-Deforestation Supply Chains* is funded by the Norwegian Agency for Development Cooperation under agreement number QZA-0464 QZA-16/0218;

Research Program Future Forests, funded by the Swedish Foundation for Strategic Environmental Research.


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Using game theory to understand cooperation

Cooperation is increasingly vital in this time of global change. IIASA researchers have been using game theory to investigate how to encourage individuals to cooperate and how to reduce as much as possible the negative impacts of non-cooperation.

Overfishing, greenhouse gas emissions, and air and water pollution: These are all examples of "tragedies of the commons," when individuals—acting according to their own self-interest—behave contrary to the best interests of the wider group by depleting or degrading a common resource. To determine how to avoid such tragedies, researchers from the IIASA Advanced Systems Analysis Program have been using a game-theoretic approach.

One of the major questions related to sustainability is how to convince people to modify their behavior in ways that reduce their consumption. A new IIASA study provides a unique new modeling framework, which translates findings from psychological research into a formula that can be applied to social and environmental perceptions and consumer behavior. The aim of this study was to see how much individual action can drive sustainable solutions, and how individuals influence each other.

The results showed that, at least in the theoretical framework, consumers' individual actions could go a long way towards optimizing the use of the shared resource. In particular, when individuals attached more relevance to information about the actions of others as compared to information about the state of the resource, they were more likely to modify their actions to reduce their own consumption.

Identifying ways to encourage individuals to cooperate remains a challenge. To tackle this, IIASA researchers developed a technique that allowed, for the first time, theoretical games to be decomposed into the portion that encourages individuals to seek personally preferred payoffs and the portion that requires cooperation among players [2].

An important form of cooperation is when society invests in protection against what are known as "contagious random attacks," such as an outbreak of a disease, a computer virus, or terrorism. Protection might therefore include vaccination programs or airport security. A recent IIASA study, using the mean-field approximation approach, shows that these different applications lead to very different equilibrium patterns of investments in protection, with important welfare and risk implications. For example, vaccination programs have a unique equilibrium in which more connected individuals are more likely to get vaccinated. However, airport security or certain types of computer security investments can lead to multiple equilibria and coordination failures [3].

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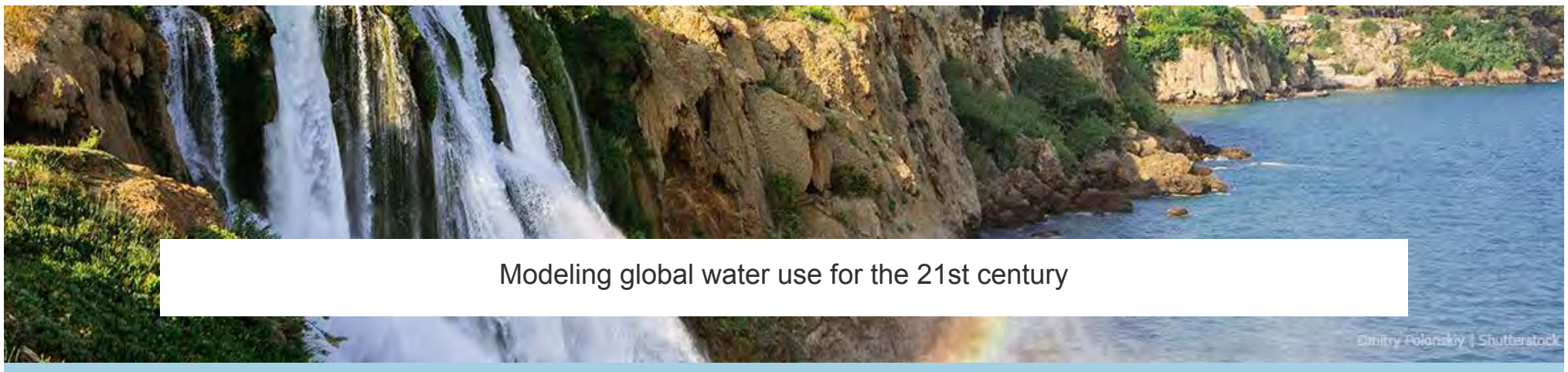
Advanced Systems Analysis Program

Collaborators

- Lahore University of Management Sciences, Pakistan
- University of California, Irvine, USA,
- European Institute of Business Administration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Modeling global water use for the 21st century

The Community Water Model, developed by the IIASA Water Program, assesses water supply and demand at global and regional levels, and includes provision for healthy aquatic ecosystem. The hydrologic model is open source and can be linked to other models, enabling analysis of many different aspects of the water-energy-food-ecosystem nexus.

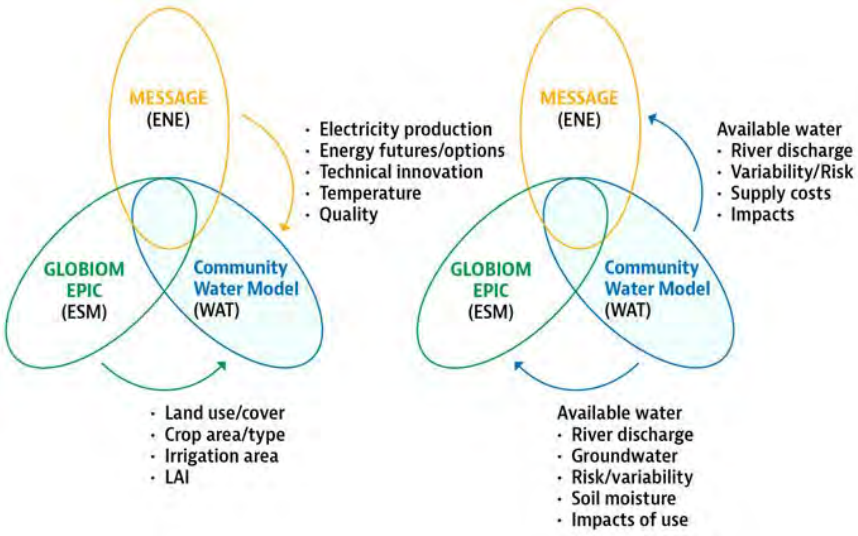
Rising population and growing economic development mean that water demand is expected to increase significantly, especially in developing regions. At the same time, climate change will have global, regional, and local impacts on water availability. Accurate assessment of water supply and demand is therefore vital, and must take into account both human water use and the amount needed to maintain healthy aquatic ecosystems. The Community Water Model will examine how future water demand will evolve in response to socioeconomic change and how water availability will change in response to climate.

The model has been developed to work at both global and regional levels at varying spatial resolutions, and the fact that it is open-source means that it provides a service to the water research and management community worldwide. In addition, it is flexible enough link to further planned developments such as water quality and hydro-economic extensions to the model.

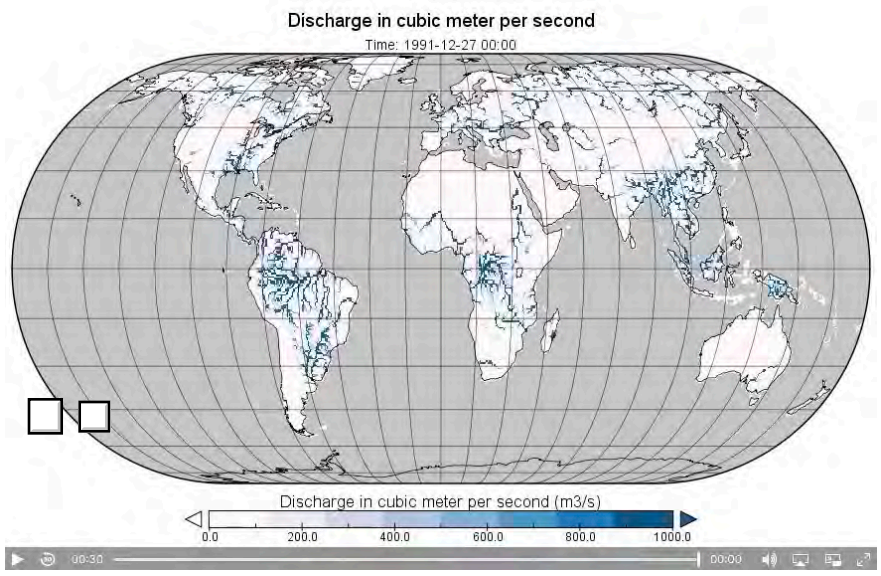
In this way, the model will provide a basis to develop a next-generation global hydro-economic modeling framework that can clarify the economic trade-offs among different water management options, encompassing both water supply infrastructure and demand management. The integrated modeling framework will consider water demand from agriculture, domestic, energy, industry, and the environment. It will also take into account the investment needed to alleviate future water scarcity, and provide a portfolio of economically optimal solutions. In addition, it will be able to track the energy requirements associated with the water supply system; for example, pumping, desalination, and interbasin transfer.

To achieve these goals, the model will be coupled to existing IIASA models, including the Model for Energy Supply Strategy Alternatives and their General Environmental Impact (MESSAGE); the Global Biosphere Management Model (GLOBIOM); and the Environmental Policy Integrated Model (EPIC).

In the short to medium term, the IIASA Water Program is working is to introduce water quality (e.g., salinization in deltas and eutrophication associated with mega cities) into the Community Water Model, and to consider qualitative and quantitative measures of transboundary river and groundwater governance



Linking models for best results. MESSAGE: Model for Energy Supply Strategy Alternatives and their General Environmental Impact from the IIASA Energy Program (ENE). GLOBIOM: Global Biosphere Management Model and EPIC: Environmental Policy Integrated Model from the IIASA Ecosystems Services and Management Program (ESM). Community Water Model from the IIASA Water Program (WAT).



The Community Water Model output, showing global discharge over a one year run example: 1/1/1991- 31/12/1992

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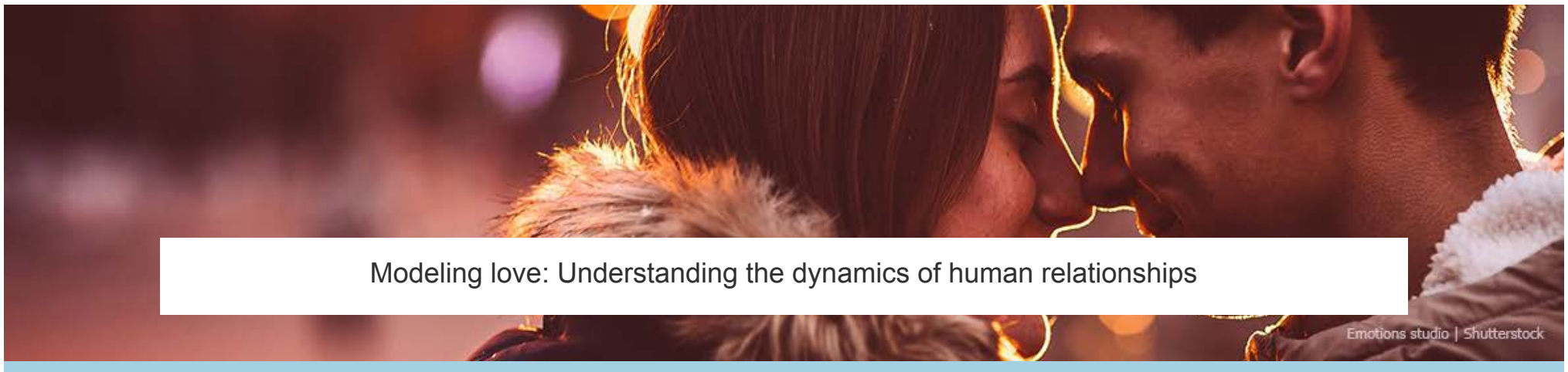
Water Program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Modeling love: Understanding the dynamics of human relationships

Is it possible to predict how love affairs will develop using mathematical models? According to the book *Modeling Love Dynamics* by researchers from the IIASA Evolution and Ecology Program and colleagues, the simple answer is yes. The message from the research is that prediction is possible, if the way each individual reacts to the love and appeal of their partner can be described in formulas.

Consider a standard love story, which develops like those described in a classic Hollywood movie such as "Titanic." This story can be modeled by considering appealing individuals who increase their own love as their partner's increases—so called secure individuals. Starting from the state of indifference, where the individuals are at their first encounter, their feelings continuously grow and tend toward a positive plateau.

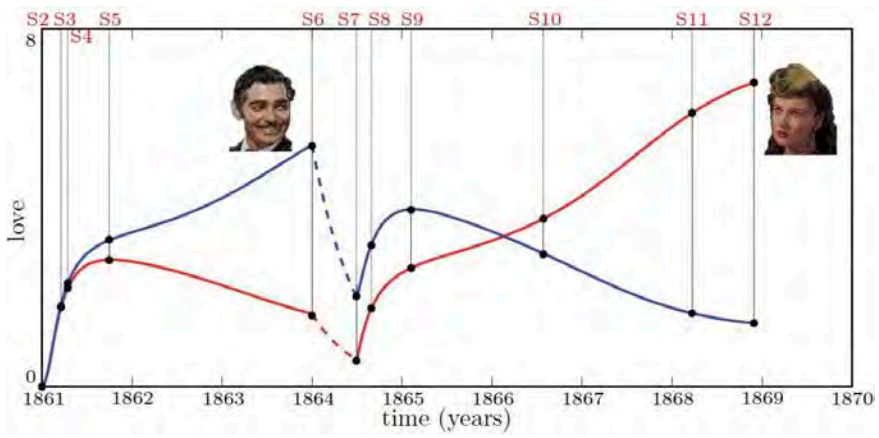
Love stories become more intriguing when one individual is not particularly appealing, if not repellant, as in the fairy tale "Beauty and The Beast." In these cases, there is a second romantic regime, which can lead to marital dissolution in the long run. In order to avoid that trap, people who are not very charming do all they can to look more attractive to the partner at first. After a while, the bluffing can stop, because the couple has entered the safe basin of attraction.

Not all individuals are secure. Indeed, some people react less strongly when the love of their partner exceeds a certain threshold. These individuals, often very keen on flirtation, are less capable of becoming one with their partner. The model shows that couples composed of insecure individuals tend, with almost no exception, toward an unbalanced romantic regime in which the most insecure is only marginally involved and is therefore prone to break up the relationship at the first opportunity. This is illustrated by the characters Scarlett O'Hara and Rhett Butler in the famous film "Gone with the Wind".

Mathematical models can also be used to interpret more complex romantic behaviors. Take the case of "biased" individuals who overestimate the appeal of their partners when they are more in love with them. Interestingly, if insecurity is also present, biased couples can have romantic regimes characterized by recurrent ups and downs. In other words, bias and insecurity is an explosive mix that makes for a turbulent relationship.

The second part of the book focuses on the effects of the social environment. In this context, the researchers analyze the 20-year relationship between the famous Italian poet Francis Petrarch and a woman known only as "Laura," showing that poetic inspiration is an important destabilizing factor, responsible for transforming a quiet relationship into a turbulent one.

Finally, the team studied triangular relationships, with emphasis on the effects of conflict and jealousy. In these cases, the dynamics of feelings can be very wild, up to the point of being chaotic and, hence, unpredictable. When this occurs, the life of the couple becomes unsustainable, because painful periods of crisis can start at virtually any moment: a heavy permanent stress.



Example of how complex human relationships can be understood as dynamical systems. The illustration refers to "Gone with the Wind", one of the most popular films of all time. The red and blue lines, respectively, show the time evolution of Scarlett O'Hara's and Rhett Butler's involvements during their love story, as predicted by the mathematical model by Rinaldi et al. [1].

References

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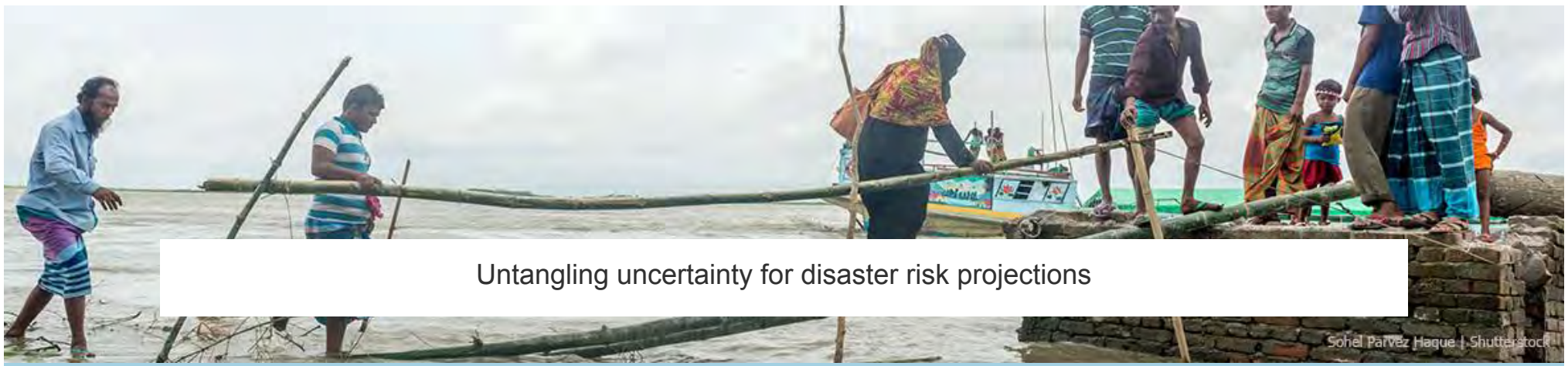
Evolution and Ecology Program

Collaborators

- Department of Electronics and Information, Politecnico di Milano, Italy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Untangling uncertainty for disaster risk projections

When assessing and understanding the risks that accompany disasters, both researchers and policymakers must grapple with uncertainties. In a study of extreme flood risk in Bangladesh, IIASA researchers show that socioeconomic uncertainty is more important to risk predictions in the short term, but climate uncertainty becomes more relevant in the longer term.

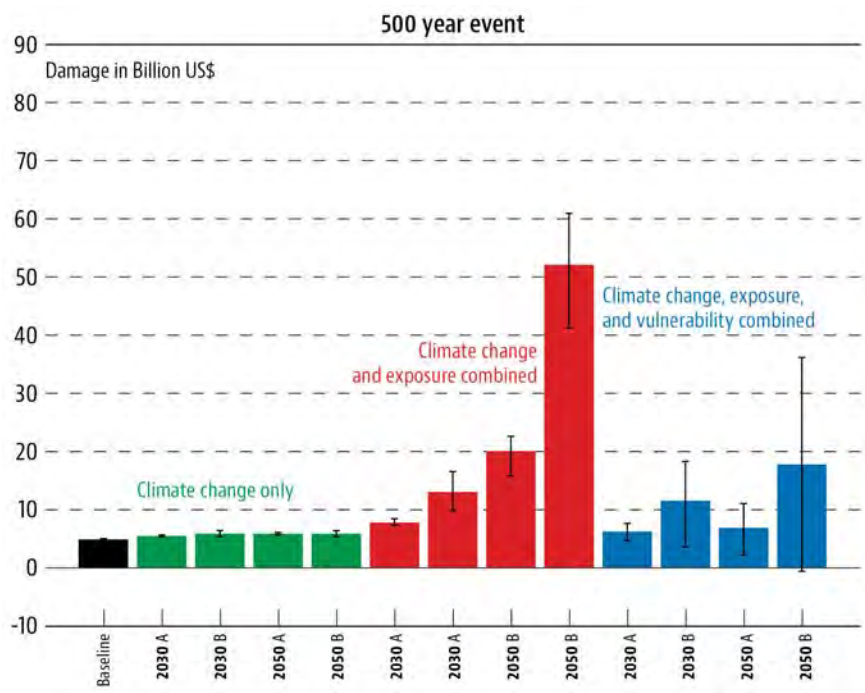
Few studies dissect the drivers of long-term risk, however this work from the IIASA Risk and Resilience Program fills this gap by using a case study of extreme flood risk in Bangladesh. The study examines how sources of uncertainty in the scenarios and models used could affect estimates of future loss caused by extreme events.

There are three main drivers of extreme risks: climate change, exposure, and vulnerability, and they affect risk in different ways. Exposure, for example, describes the assets such as houses or infrastructure that are at risk. The greater the number of houses on a flood plain the greater the exposure. Socioeconomic development can affect exposure in particular because if more houses are built there is also a higher possibility that more will get damaged, irrespective of climate change or vulnerability changes.

By examining different assumptions regarding climate, exposure, and vulnerability the researchers showed that scenario uncertainty regarding socioeconomic development seems to contribute the most to the variability in results.

While socioeconomic uncertainty is more dominant than climate change uncertainty, the longer the timescale considered, the larger the relative contribution of climate uncertainty to the estimated economic loss. The figure shows the losses for a 500 year event: for 2030 and 2050, under two climate scenarios A and B, looking at either climate change impact only, climate change and exposure impacts combined, or the full combination of climate change, exposure, and vulnerability combined.

This shows that while climate change and increases in housing and infrastructure assets may cause devastating impacts in future extreme events (see column 2050 B in the 'climate change and exposure combined' category) reducing in vulnerability can also significantly decrease losses (see column 2050 B in the 'climate change, exposure, and vulnerability combined' category).



Mean and standard deviation of loss estimate under alternative scenarios for Bangladesh flood risk (in billion US$). Baseline is the current risk.

A systems perspective taking all three drivers into account—climate change, exposure, and vulnerability—is needed to inform policy targets and implementation according to different timescales. The research has important implications for decreasing future extreme risks at national levels. Freeing countries from the burden of these losses will also help them to achieve the Sustainable Development Goals.

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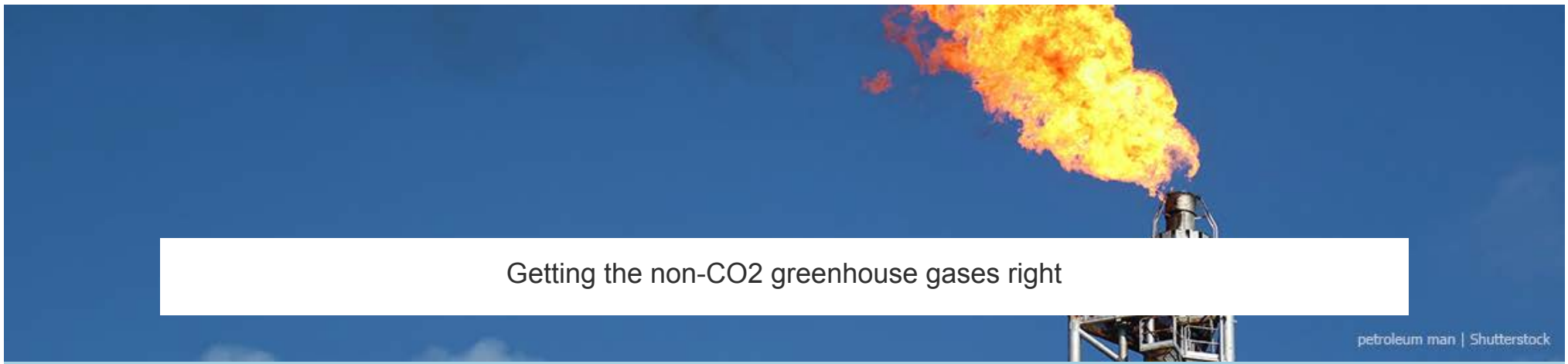
Risk and Resilience Program


petroleum man | Shutterstock

Getting the non-CO2 greenhouse gases right

There are many important greenhouse gases besides CO_2: in fact they account for about 20% of total greenhouse gas emissions in the EU. The IIASA Air Quality and Greenhouse Gases Program has developed new methods to investigate the three most important—methane, fluorinated gases, and nitrous oxide—determining how much is released, how to reduce their emissions, and what the costs of this will be.

Gas flares are used in oil production to burn off waste gas but occasionally they fail to burn, releasing methane—a greenhouse gas about 30 times more potent than CO_2. These releases have long been underestimated in national emission inventories because no one has attempted to systematically monitor the volumes of gas that escape during this 'cold venting.'

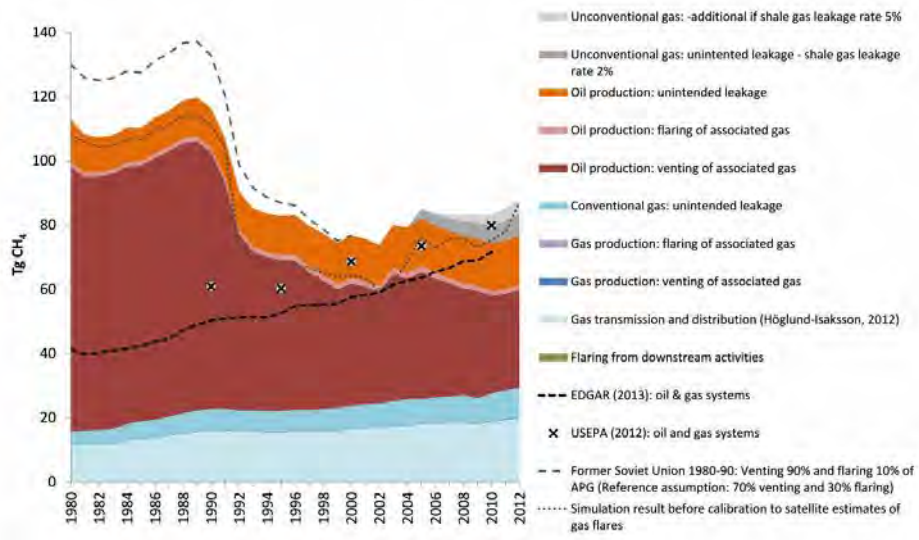
To address this, an IIASA study brought together all available information on the handling of gases released through oil production for around a hundred countries. The team used this to derive global estimates of the volumes of gas flared and vented that are consistent both with country-specific flaring volumes estimated from satellite images, and total generation and recovery of gas taken from energy statistics. Only in Canada have direct measurements of venting been taken, and these patterns were therefore used for all countries. The results demonstrated that methane emissions where much higher than previously estimated [1].

The study also examined ethane, which is a better tracker for these emissions than methane, because it does not last long in the atmosphere, and oil and gas production is its dominant source. Ethane emissions estimated using the improved method correspond remarkably well to top-down atmospheric measurements, explaining much of the existing divergence between bottom-up and top-down estimates [2].

Global oil and gas systems are estimated to have released about 3 metric gigatons of methane over the study period 1980-2012, which will cause the same amount of global warming as about 100 billion metric tons of CO_2 over 100 years. For the earlier years, this means more than double the corresponding methane emissions estimated by the US Environmental Protection Agency and Electronic Data Gathering, Analysis and Retrieval databases.

Fluorinated gases, commonly used as cooling agents in refrigerators and air conditioners, also have a strong greenhouse effect. They have come under increasingly stringent regulations, including the Kigali Agreement, which was signed by 170 countries in 2016. To estimate the current and future releases of fluorinated gases under the new rules, IIASA researchers developed a tool in the Greenhouse Gas – Air Pollution Interactions and Synergies model.

The tool can also be used to estimate the costs for complying with the agreement from 2016 to the phase-out of these gases in 2050 [3].



Methane emissions from global oil and gas systems when using new estimation methodology and in comparison to existing bottom-up inventories from US Environmental Protection Agency and Electronic Data Gathering, Analysis and Retrieval.

The third most important greenhouse gas is nitrous oxide, but it is often ignored in climate mitigation measures. Its main anthropogenic source is agriculture, and by analyzing global emissions of the gas from atmospheric concentration measurements, IIASA researchers concluded that under standard agricultural practice biofuel production will typically cause more greenhouse gas emissions in the form of nitrous oxide than it will save on fossil fuel CO_2 emissions [4]. Although they are not adequately enforced, laws for the regulation of this potent greenhouse gas do exist. For instance, IIASA research found that the US Clean Air Act provides considerable authority to reduce national nitrous oxide emissions, even though it was designed to address its ozone depleting, rather than global warming, properties [5].

Air Quality and Greenhouse Gases Program

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Shared Socioeconomic Pathways: Finding routes to sustainability

How can we predict the challenges of climate change without making judgments about the social, political, and economic paths the world might take? The Shared Socioeconomic Pathways provide these possible narratives, allowing climate modelers to compare their projections and develop robust policy advice. These pathways were the subject of a 2016 special issue of the journal *Global Environmental Change*, compiled by the IIASA Energy Program.

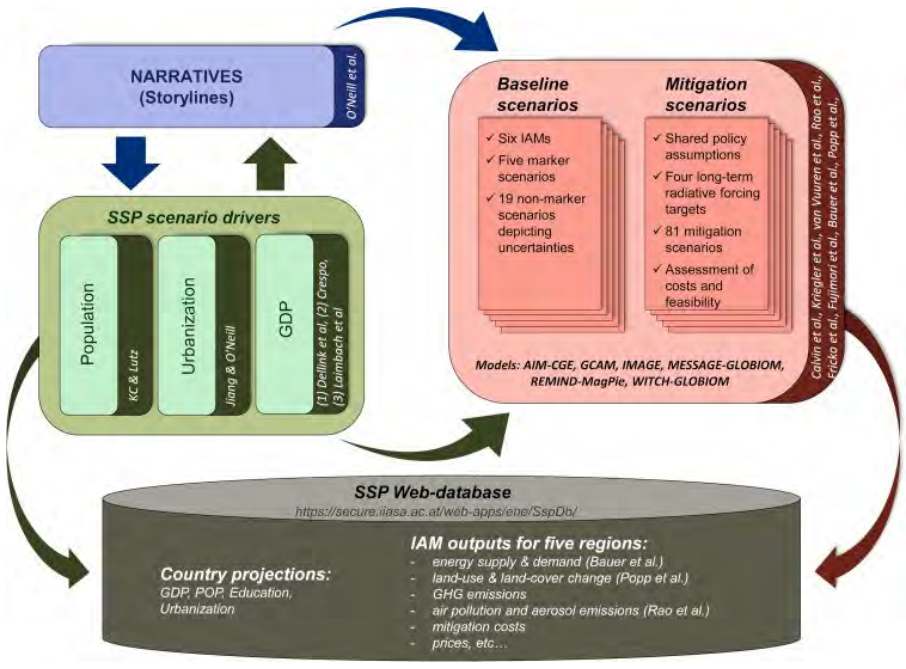
The Shared Socioeconomic Pathways (SSPs) are five possible paths human societies could follow over the next century. Designed by and for the climate change research community to use as a basis for their models, the SSPs span a wide range of feasible future developments in areas such as population, the economy, and agriculture.

The pathways were developed in recent years to describe plausible major global developments that would together lead to different challenges for mitigation and adaptation to climate change. The SSPs are based on five narratives describing alternative socioeconomic developments, known as: sustainable development, regional rivalry, inequality, fossil-fueled development, and middle-of-the-road development.

Analyzing the different ways to mitigate climate change, the researchers found that the costs of mitigation were lowest in the sustainable development and inequality scenarios and highest in the fossil-fueled development and regional rivalry pathways.

Perhaps most importantly, the studies find that not all targets are necessarily attainable from all of the pathways. Specifically, keeping temperature change to about 2°C was not feasible when following the regional rivalry pathway. This narrative describes a possible future where resurgent nationalism, concerns about competitiveness and security, and regional conflicts push countries to increasingly focus on domestic or, at most, regional issues.

The next steps of the process, organized as part of the Scenario Model Intercomparison Project [1], will involve collaboration with the climate modeling teams of the Coupled Model Intercomparison Project 6 to assess the climate consequences of the SSPs. The work also provides important services to the research community, including a detailed modeling protocol for integrated assessment modeling teams to enable widespread participation in quantifying the SSPs.



The main steps in developing the SSPs, including the narratives, socioeconomic scenario drivers (basic SSP elements), and SSP baseline and mitigation scenarios.

The SSPs provide researchers with the means to explore climate change impacts, adaptation, and vulnerability under a range of possible socioeconomic developments and climate change projections. The pathways provide a common grounding so that a large body of literature based on comparable assumptions can emerge.

Energy Program

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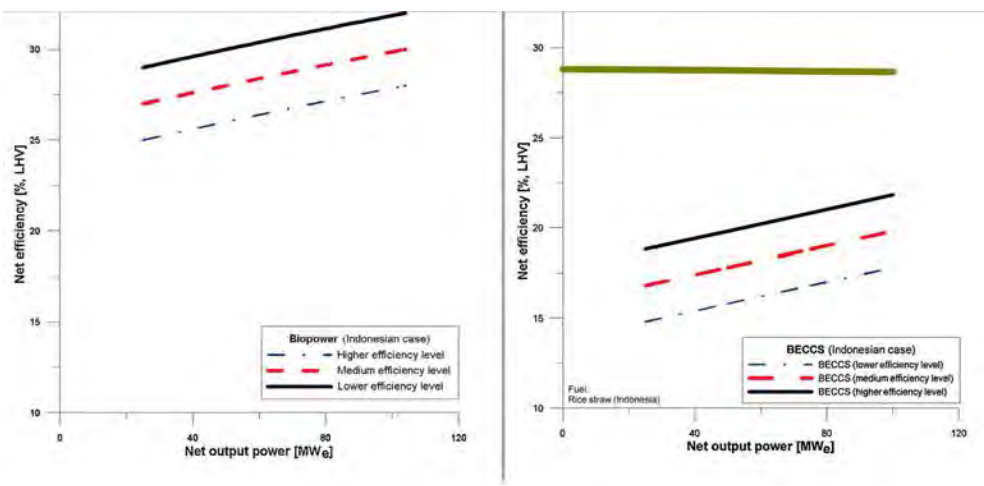
Negative emissions in the tropics

Many of the options proposed for achieving a stable climate rely on 'bioenergy with carbon capture and storage'— burning plant matter for energy, capturing the carbon, and storing it underground. Under the IIASA Tropical Futures Initiative, researchers explored optimal strategies for harnessing negative emissions in South East Asia—in particular Indonesia.

While there is a strong scientific consensus that we need to aggressively cut greenhouse gas emissions immediately, there is also growing evidence that we may not be able to achieve the necessary reductions in the time available. This means that we may need a way of removing CO_2 already in the atmosphere — a process known as negative emissions.

Negative emissions can come in many forms: from simply planting more trees, to crushing rocks that naturally absorb CO_2. One widely considered option is using plant matter as a fuel to produce energy, then capturing the CO_2 that is emitted and storing it underground. This is known as bioenergy with carbon capture and storage (BECCS).



Trajectories of biopower plant net efficiency without carbon capture and storage (left), and the resulting net efficiency of co-fired biomass and biopower with carbon capture and storage (BECCS, right) depending on plant size (net power output).

This latter technology is cited by research as being an important part of restricting warming to safe — or at least safer — levels since it contributes to both carbon sequestration and decarbonization of the energy system. In fact, more than half of the future scenarios that give at least a 66% chance of limiting warming to 2°C, which were developed for the Intergovernmental Panel on Climate Change (IPCC), feature BECCS.

A recent IIASA study addresses deployment of BECCS in Indonesia, examining whether adapting existing coal-fired power stations so that they can burn a mix of coal and plant waste from agriculture (such as seed kernels or stems that are usually discarded), is more effective than building specific biomass-burning power stations.

The team found that although both options saved the same amount of CO_2, the combined stations were more efficient, producing more electricity for the amount of biomass burnt. More efficiency means that burning biomass in adapted coal-fired power stations would be more economically viable.

It is also likely to be easier and cheaper to convert existing coal power stations than build new specific biomass-burning stations. With lower investments and existing infrastructure, policymakers and other stakeholders are more likely to embrace the idea.

There are limitations: for instance, the study results indicate that under the current conditions it is not possible to burn any more than 30% biomass in a combined power station. There are also uncertainties surrounding whether it is possible to collect enough biomass on the scale needed. However, the results are broadly general, and can be applied to other countries and situations, making them a valuable starting point.

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Tropical Futures Initiative

Collaborators

SINTEF Energy Research

Sustainable fisheries management

Both evolutionary and ecological factors interact to influence the growth and size of fish, an IIASA study has shown. Previous work demonstrated that overfishing can lead to evolutionary changes in fish populations, but in a 2016 study the researchers show that a comprehensive perspective on evolutionary and ecological processes is needed in order to understand and manage fisheries sustainably.

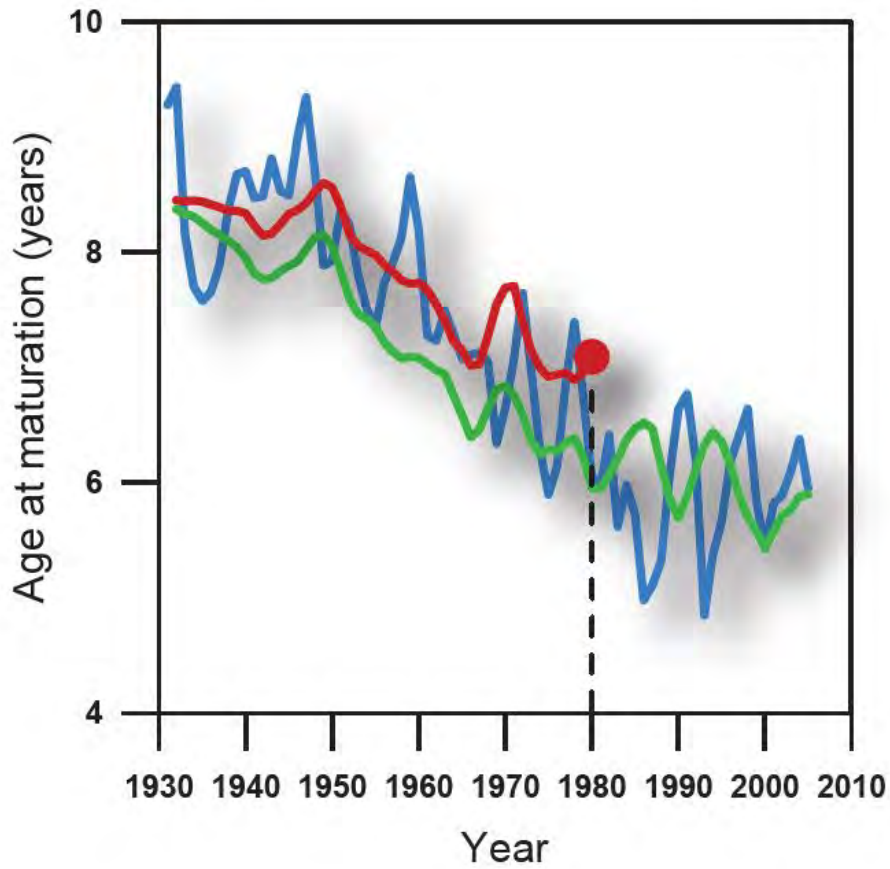
Because fishers usually harvest larger fish, fish populations adapt to the pressure of heavy fishing by evolving to mature earlier and at smaller sizes. This phenomenon is concerning both for the economy and the environment: economically because smaller fish means a smaller catch for fishers, and for the environment because the broader ecosystem impacts of these changes are unclear.

Through a growing body of research, the IIASA Evolution and Ecology Program is elucidating to what extent observed changes in fish populations are caused by non-reversible genetic changes, or evolution, and to what extent the changes are phenotypic, or influenced by the environment rather than genetics. The distinction is crucial for sustainable management, since fisheries-induced genetic changes tend to be slow or impossible to reverse.

In the study, the researchers addressed this question by exploring the relative impact of two factors: density dependence, meaning that when the cod population shrinks through fishing, more food is available, so that fish can grow faster and mature earlier; and life-history evolution, meaning that a trend towards genetic changes causing earlier maturation is induced by the selective harvesting of larger fish.

Using an eco-evolutionary model that could reproduce 74 years of historical data on age and length of maturation in Northeast Arctic cod, they found that a combination of these two factors was likely responsible for the observed changes in fish size. Their carefully calibrated quantitative model also revealed that the cod population might have collapsed around 1980 had it not undergone some life-history evolution that made it more resilient to the high fishing pressures it experienced after World War II.

The study thus shows that ecological and evolutionary dynamics do not work in isolation, but rather as part of a complex system. In order to prevent fisheries collapse, it is important to understand these dynamics and how they interact.



Fisheries-induced evolution causes Northeast Arctic cod to mature at younger ages and smaller sizes. Blue line: Empirical observations. Green line: Eco-evolutionary model predictions. Red line: Non-evolutionary model predictions. The results suggest that without fisheries-induced evolution, high fishing pressures could have caused the stock to go extinct in the 1980s (red circle).

Evolution and Ecology Program

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Collaborators

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- Center for BioComplexity, Princeton University, USA Princeton Environmental
- Institute, Princeton University, USA Department of Ecology and Evolutionary Biology, Princeton University, USA
- Aquatic Research and Monitoring Section, Ontario Ministry of Natural Resources and Forestry, Canada
- Institute of Marine Research, Norway
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- Statistics Division, Department of Mathematics, University of Oslo, Norway

Further information

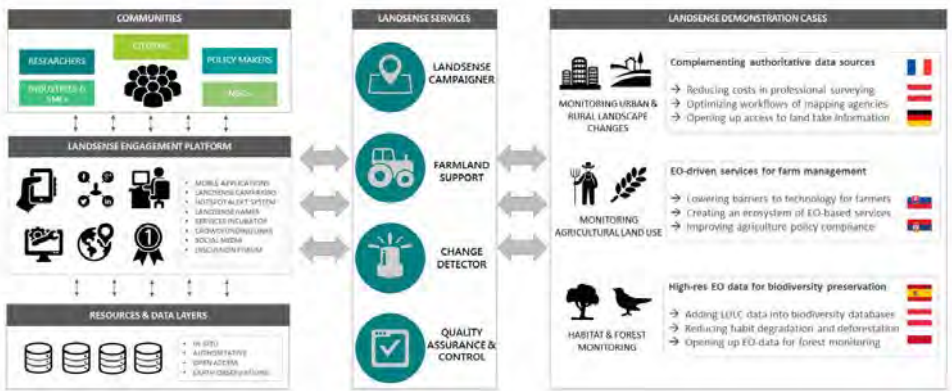
Interview: Are we accidentally genetically engineering the world's fish?
The evolution of fish and fisheries


Budimir Jevtic | Shutterstock

Harnessing the power of citizen science

Land-use change can have far-reaching impacts on issues as broad as flood resilience, food security, air pollution, and biodiversity protection. Monitoring it is therefore crucial, and one effective and cheap way to do it is to engage citizen scientists. In 2016 the IIASA Ecosystems Services and Management Program furthered its pioneering work in citizen science, exploring how to encourage people to take part, assessing the quality of the data, and launching a citizen science observatory.

In 2016, a new IIASA-led project, *LandSense*, was launched to link remote sensing with citizen-science data collection. The citizen science observatory includes an engagement platform that hosts various services and tools for collecting and sharing data from satellites and citizens. The citizen science campaigns run by the project will help monitor resources in both urban and rural contexts, in select regions of Austria, France, Germany, Spain, Slovenia, and Serbia, as well as beyond Europe in Indonesia.



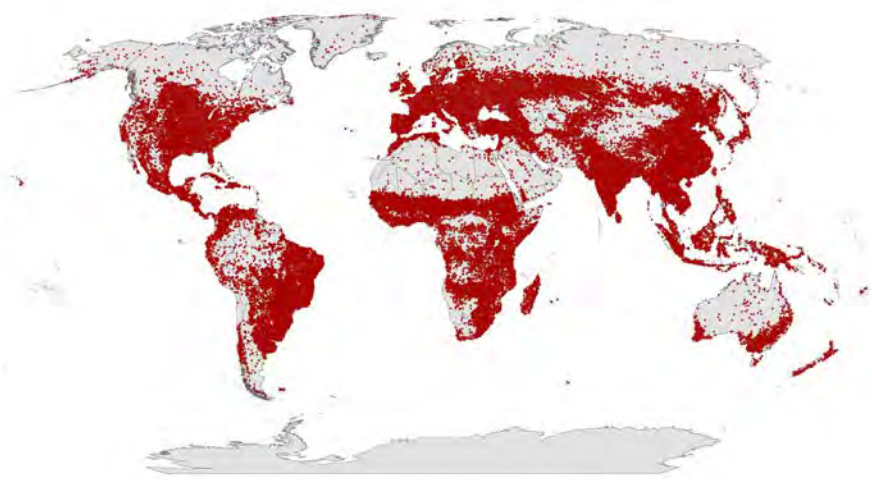
The concept underpinning the LandSense Citizen Observatory

Citizen science data can play an important role in long-term, accurate monitoring of agricultural production—crucial to policies to increase food security and reduce food price volatility. In 2016, as part of the EU-funded *Stimulating Innovation in Global Monitoring of Agriculture* project, IIASA researchers helped validate and improve a key map of cropland distribution using its suite of crowdsourcing land cover tools, collectively known as Geo-Wiki.

Two key concerns when using citizen science data for such purposes is the quality of the data and the need to engage a large number of people. The Land Use Cover Area Frame Sample is an EU land-cover and land-use change survey, which takes place every three years. The data needed can be collected by citizens, using the IIASA-developed mobile phone application FotoQuest Austria, for example. However, the quality of the data was in question.

As part of the European Research Council-funded project *Crowdland*, IIASA researchers compared the data collected by the citizens with those of the professional surveyors. The results showed that both land cover and land use could be crowdsourced with an accuracy of about 80%. This represents a new source of potentially valuable information for the validation of land cover maps, is much cheaper than a professional survey, and has the advantage that the data can be collected continuously over time.

Motivation among citizens, however, is very uneven. Mobile applications that involve user-generated content generally have 90% of the content provided by only 1% of the users. Of those remaining, 9% of users provide content some of the time while 90% use the content but do not contribute anything [1].



Validation data gathered in the SIGMA crowdsourcing campaign

The IIASA Ecosystem Services and Management Program has run three campaigns to increase the percentage of users providing content. For Picture Pile, contribution to the science was the only incentive, but for FotoQuest Austria small prizes were also introduced. For Geo-Wiki, Amazon vouchers and coauthorship on a scientific publication led to rapid uptake by users. Rapid feedback and regular interaction with the participants was also a key part of this campaign and had noticeably positive effects on participation.

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Ecosystem Services and Management Program

Collaborators

The SIGMA project is led by the Belgian company VITO with a consortium of 22 EU and international partners

LandSense is led by IIASA with a consortium of 17 EU partners including 5 research institutes/universities, 5 small medium enterprises, 3 NGOs, 3 government bodies and the European Citizen Science Association, a list of collaborators can be found here.

Reaping the co-benefits of air pollution and climate policies

For more than a decade, the IIASA Air Quality and Greenhouse Gases Program (AIR) has pioneered the analysis of the co-benefits of climate policies on local air quality and human health. Continuing this work in 2016, the program has fostered close collaborations with the energy research community, demonstrating that many solutions to reducing emissions and improving health lie within the energy sector.

Air quality and climate policies can provide substantial mutual benefits: climate change mitigation actions can help reduce air pollution, and clean air measures can help reduce greenhouse gas emissions.

In 2016, a collaborative project using the Integrated Model to Assess the Global Environment confirmed that, because of the overlap between greenhouse gas and air pollutant emission sources, climate mitigation policies have the highest impact on emissions of sulfur dioxide and nitrogen oxides, while their impact on black carbon (soot) and organic carbon emissions is relatively low. At the global scale, climate policy can have important co-benefits; a 10% decrease in global CO_2 emissions by 2100 leads to a decrease of emissions of sulfur dioxide and nitrogen oxides by about 10% and 5% respectively, compared to 2005 levels [1].

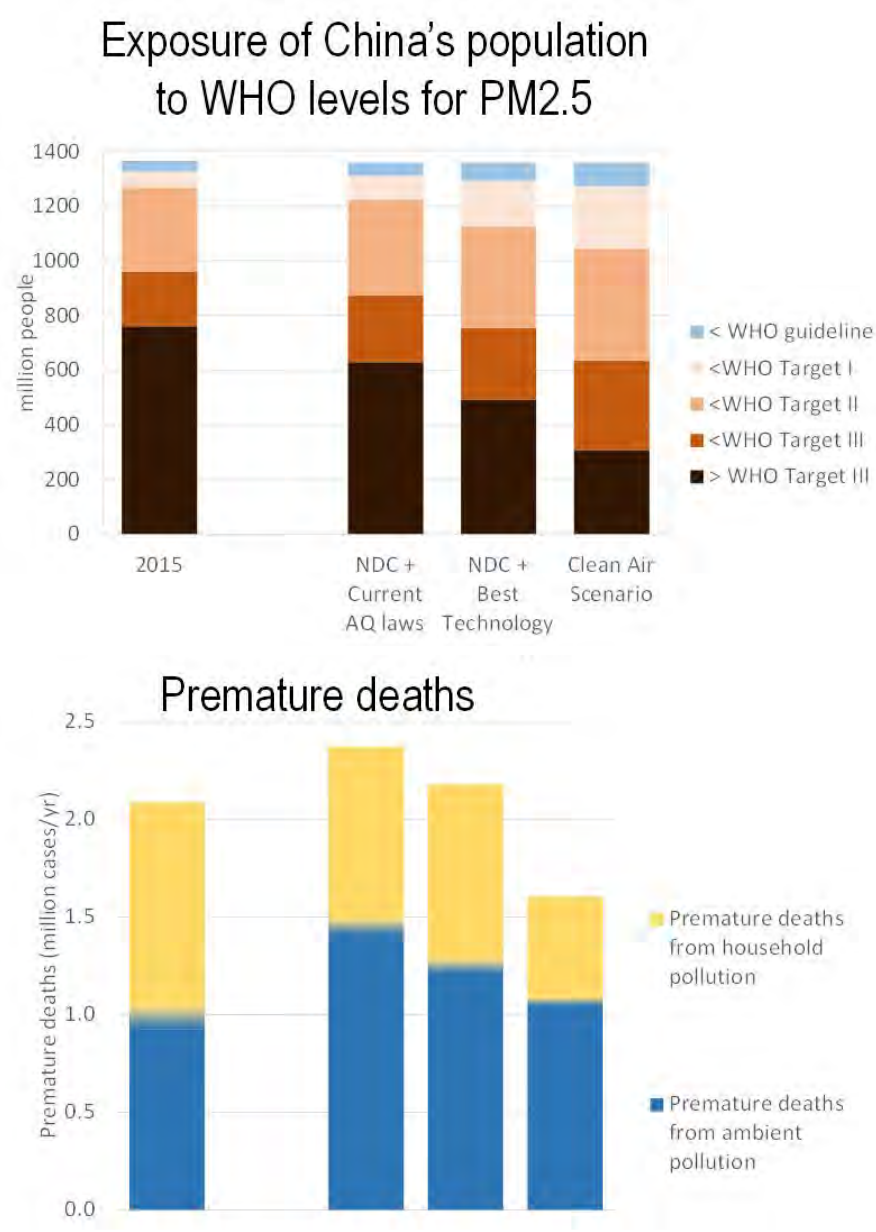
Energy production is, of course, central to both climate change and air pollution issues, and AIR has recently been working with the institute's Energy Program, as well as a number of external energy modeling groups. The researchers explored various pollution control policies, complemented by climate mitigation policies that foster technology and fuel transformations in energy systems.

The results showed that a combination of stringent air pollution policies and climate change mitigation could provide clean air to about 60% of the world's population, with the largest improvements in India, China, and the Middle East. The study reinforces the importance of integrated policies that address multiple sectors in achieving the UN Sustainable Development Goals [2].

The critical role of policy decisions in the energy sector to securing clean air was also the topic of a study undertaken with the International Energy Agency [3]. Many solutions to reducing emissions and improving health and living conditions lie within the energy sector, the study confirmed. However, aging and urbanization will counteract the health benefits of policy measures, and even tighter measures will be needed if the aim is to reduce the total health burden in future.

While recognizing that non-energy related sources make substantial contributions to air pollution, especially in developing Asia, the study demonstrated that a comprehensive 'Clean Air' approach, building on proven measures and policies, offers a cost-effective way for the energy sector to reduce health impacts from air pollution.

Air Quality and Greenhouse Gases Program



Although effective implementation of air pollution control strategies will reduce population exposure to harmful pollution (upper panel), the actual health benefits will be counteracted by the aging of societies, because the elderly are more sensitive to air pollution. Source: IEA 2016

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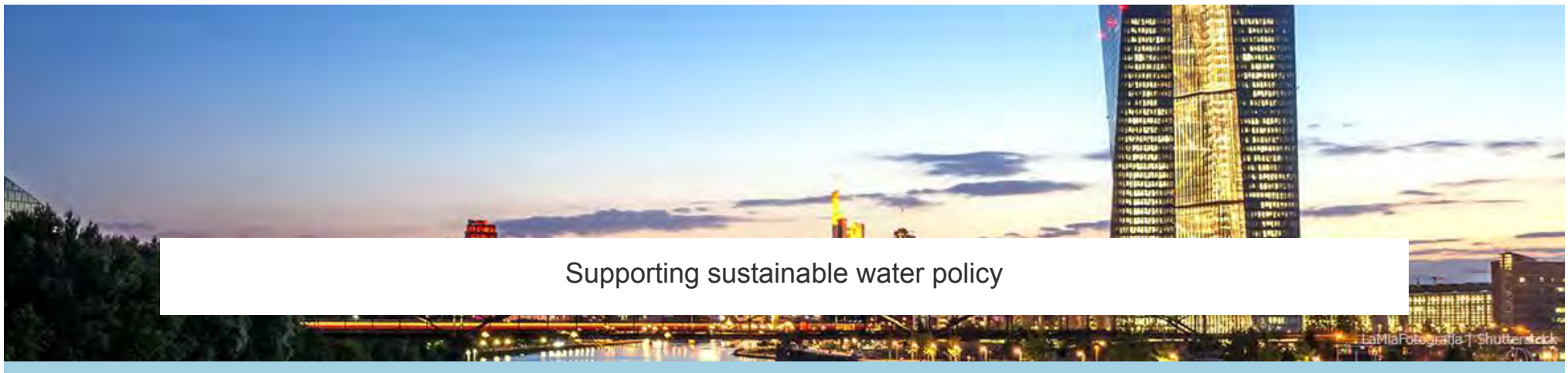
Collaborators

- Netherlands National Institute for Public Health and the Environment (RIVM) Integrated Model to Assess the Global Environment group (Detlef van Vuuren)
- Joint Research Centre for the European Commission, Ispra, Italy (Frank Dentener)
- International Energy Agency



Supporting sustainable water policy

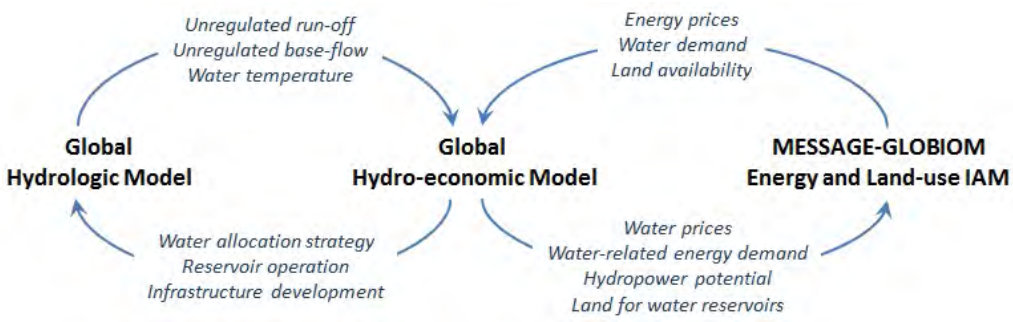
Climate change and growing demand mean that competition for scarce water resources is increasing worldwide. The consequences for the environment and the global economy could be severe. The Global Hydro-economic Model, currently under development by the IIASA Water Program, can be used to simulate a wide range of possible future scenarios, supporting policymakers to create cost-effective, long-term sustainable water management policies.

The pressure on water resources has been mounting worldwide, with water scarcity becoming a widespread problem in most arid and semiarid regions around the world. Global water extractions have increased more than six fold in the last century, which is more than twice the rate of human population growth [1]. However, the impact of growing water scarcity on long-term sustainable development has not been adequately addressed by the integrated assessment research community.

Specifically, the allocation of water resources across regions and sectors at the global level remains largely unaccounted for in long-term modeling. To reconcile potential inconsistencies introduced by constraints on future water availability, IIASA researchers are developing the Global Hydro-economic Model, which will integrate spatially distributed water resource systems, infrastructure, management options, and economic values. In addition, it will be possible to link it with other IIASA integrated assessment models: the Community Water Model; the Model for Energy Supply Strategy Alternatives and their General Environmental Impact; and the Global Biosphere Management Model.

The Global Hydro-economic Model uses optimization to balance global water demand and supply at the level of large-scale river basins. The technique allows the model to minimize the total costs of meeting the water demands from the agricultural, industrial (energy and manufacturing), and domestic sectors, while also taking into account various resource, institutional, and environmental constraints, such as retaining enough water for healthy aquatic ecosystems.

Monthly variation will be included so the model can align with existing IIASA integrated assessment models. The model can be used to simulate a variety of basin management decisions including resource extractions, interbasin transfers, reservoir storage, and water infrastructure investment (i.e., the choice of the size and location of new water projects). The model uses information on water demand and availability provided by existing global integrated assessment models at IIASA and provides information on water resources development and allocation to those models.



The proposed integration of the Global Hydro-economic Model with other IIASA integrated assessment tools.

The development of the Global Hydro-economic Model, which involves several different programs at IIASA (the Water, Energy, and Ecosystem Services and Management programs) is carried out as part of the larger *Integrated Solutions for Water, Energy, and Land* project.

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Water Program

Disaster forensics: Detecting best practice

Disaster forensics—learning about the successes and failures in disaster risk management and resilience—will be vital if we are to adapt to our changing world. The IIASA Risk and Resilience Program have helped develop a new methodology, known as the post-event review capability (PERC) approach, for systematically analyzing disaster events and identifying actionable recommendations.

The risk of disasters such as floods is on the rise, and there is an urgent need to improve our understanding and response to these events. The PERC methodology—developed by IIASA, the Zurich Insurance Group, and the Institute for Social and Environmental Transition-International—systematically and holistically analyzes disasters, helping those in the field to learn from successes and failures in disaster risk management and resilience. It also helps to uncover the underlying drivers of increasing risk. Unique in the disaster forensics field because of its policy-oriented and holistic focus, the PERC methodology is designed to generate objective, politically neutral insights and actionable recommendations in a policy-relevant timeframe following a disaster event.

The PERC approach has been applied seven times to date: for the floods in southern Germany in 2016; the floods in Columbia and Charleston, USA in 2015; the floods in Benevento, Italy in 2015; flooding and storm damage from storm Desmond in the UK in 2015; the floods in Algarve, Portugal in 2015; the floods in Guelmim and Sidi Ifni, Morocco in 2014; the floods in Karnali, Nepal in 2014; the floods in Emmental, Switzerland 2014; the Balkan floods (Bosnia and Herzegovina, Serbia and Croatia) in 2014; storm Xaver in the UK in 2013; the Boulder floods in the USA 2013; the Central European floods in 2013 (Austria, Czech Republic, Germany, and Switzerland).

By carrying out a meta-analysis of these different case studies, IIASA researchers demonstrated that policymakers and practitioners in disaster risk management face strikingly similar challenges across the globe, despite their different contexts. This indicates that there is good potential for mutual learning.

The case studies also highlight the importance of integrated risk reduction strategies, which combine risk reduction (e.g., building dikes), preparedness (e.g., early warning systems), and risk financing (e.g., insurance).

IIASA researchers are now encouraging others in disaster risk management to use the PERC approach—which is freely available to all—and to contribute to building a repository of learning for disaster risk management and resilience.

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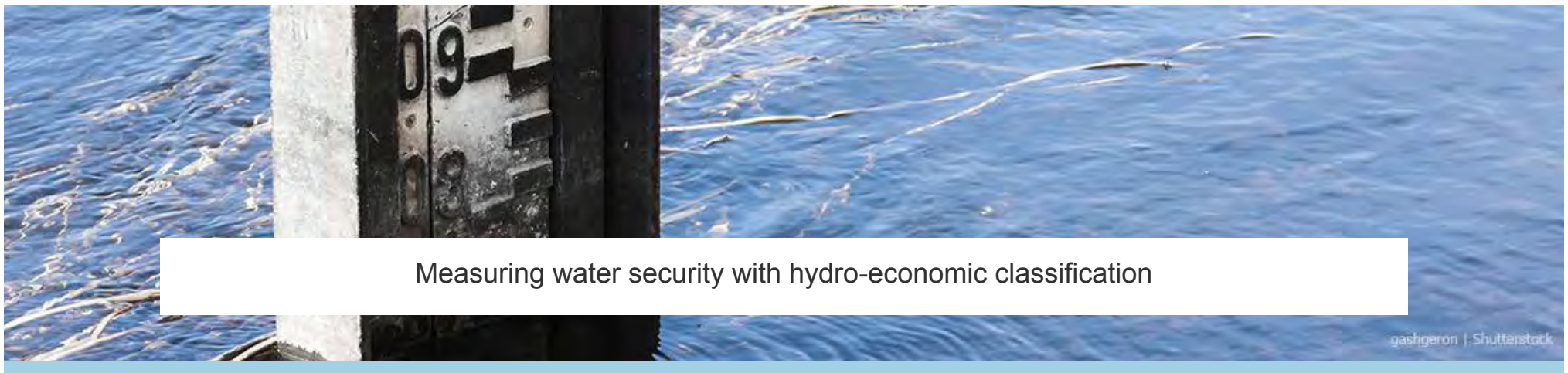
Risk and Resilience Program

Collaborators

- Zurich Insurance Group
- Institute for Social and Environmental Transition-International



Measuring water security with hydro-economic classification

A novel method to measure water security has been further developed by the IIASA Water Futures and Solutions Initiative. The hydro-economic classification uses two different dimensions to measure water security: the complexity of the hydrology and human water use, and the coping and adaptation capacity.

The IIASA-developed hydro-economic classification evaluates watersheds, countries, or regions using a combination of hydrological complexity and economic-institutional coping capacity [1]. In this way, it can identify vulnerable regions where the prevailing hydro-climatic conditions for human water use are complex and economic-institutional coping capacity is low.

Hydrological complexity is defined on the basis of four indicators:

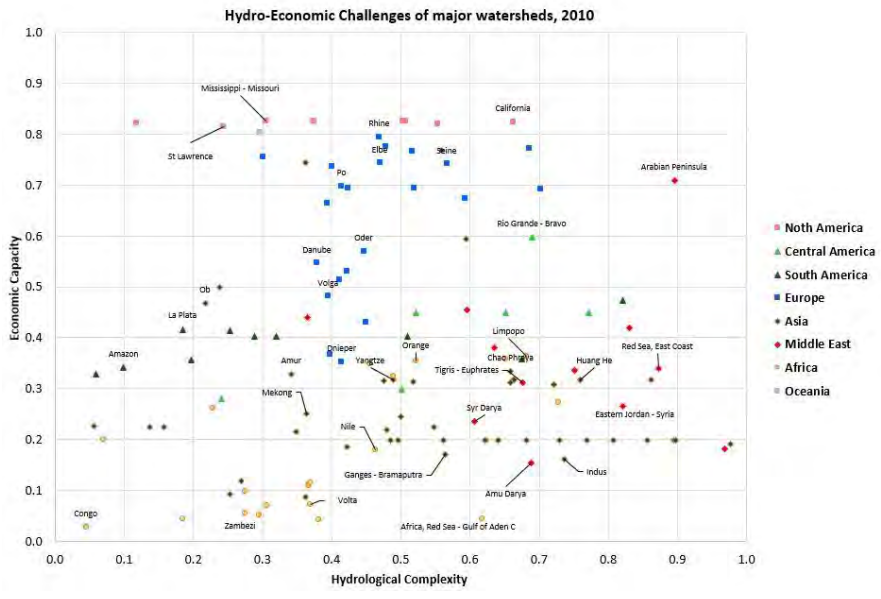
- A measure of water availability, defined as total renewable water resources per capita
- A measure of the relative intensity of water use, defined as the ratio of annual water withdrawal for agriculture, industry, and the domestic sector to the total renewable water resources
- The runoff variability, defined as the variation in monthly runoff for a 30-year period showing both inter- and intra-annual variability
- A measure of the dependency on external water resources, defined as the ratio of external (i.e. from outside national boundaries) water resources to total renewable water resources.

All four indicators were compiled based on data and model calculations consistent with the Representative Concentration Pathways (four greenhouse gas concentration trajectories), and the Shared Socioeconomic Pathways (five possible paths human societies could follow over the next century), which together provide the foundation for global climate modeling.

For economic-institutional coping capacity, researchers selected GDP per capita as a measure of economic strength and financial resources available for investing in risk reduction and adaptation. Although there are some exceptions, GDP per capita can also often provide a proxy for the availability and efficiency of institutions to cope with complex hydrological conditions.

The researchers are also discussing other potential indicators to be included in a measure of economic-institutional coping capacity. For example: education level [2], the Human Development Index, the Worldwide Governance Indicators, the Corruption Perception Index, and the Fragile State Index are all being considered.

The hydro-economic classification can group countries or watersheds into regions facing similar water security challenges and capacities. The Water Futures and Solutions Fast-Track scenario assessment [3] has applied this grouping method to differentiate key drivers of water demand and thereby go beyond globally uniform assumptions.



Watersheds with a population over 10 million people. Less water secure watersheds can be found in the lower right corner of the figure (e.g., Middle East and some Asian ones), while the upper left corner shows basins with higher water security (e.g., North American and European ones)

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Water Futures and Solutions Initiative

Sustainable transport through agent-based modeling

People's environmental actions—such as buying an electric car—are profoundly influenced by those around them, with social network interactions and peer effects compensating for a decade's delay in carbon tax introduction and allowing it to be 30% lower. These findings were the results of pioneering agent-based modeling work from the IIASA Transitions to New Technologies Program (TNT).

Individual choices and environmental awareness are an essential part of achieving sustainability; not least because people are more likely to make sustainable choices if those around them do. These so-called peer effects were the focus of work as part of the *Alternative Pathways to Sustainable Development and Climate Stabilization* project, a joint effort between the TNT and Energy (ENE) programs, and colleagues at the Research Institute for Innovative Technologies for the Earth, Japan. After much model development in previous years, the novel agent-based models were sufficiently developed in 2016 to be tested in empirical calibrations with a focus on vehicle choice adoption and transportation systems transitions, which are a traditional weakness of highly aggregated integrated assessment models.

As a calibration exercise, TNT researchers used an agent-based model to replicate the results of a discrete-choice model of the vehicle market in North America, which had been developed by ENE and colleagues. The excellent congruence between these two contrasting modeling approaches enabled the researchers to isolate the effects of social network interactions and peer effects in agent-based modeling scenarios. The model simulations meant they could quantify the market impact of social network and peer effects: by "switching them off," they could determine how much earlier and higher traditional economic incentives such as carbon taxes would have to be to yield comparable market outcomes.

The results are highly instructive for climate policy. Social network and peer effects—which can be enhanced by new information and communication technologies—can compensate for a decade's delay in carbon tax introduction and allow the tax to be 30% lower. Motivating environmentally conscious consumers can therefore be an effective climate policy, especially in cases where early and sufficiently stringent economic climate policy is not possible.

In a second calibration exercise, TNT researchers modified the existing agent-based model of vehicle choice and tested it using real-world data on the vehicle market (conventional and electric) in Shanghai, China. The city was chosen because the electric vehicle market is particularly large and dynamic (rivalling markets such as California, USA, or Norway).

The researchers used historical data for both conventional and electric vehicles and then performed simulations of future market growth under a range of policy scenarios. Currently, economic incentives for electric vehicle purchases in Shanghai are unparalleled, including both federal and local government subsidies, as well as a waiver on a car registration fee that is roughly the price of a medium-sized car.

If these strong economic incentives continue, a market penetration of electric vehicles of 80% by 2040 is possible in the scenarios modeled. Social network and peer effects can compensate, to a degree, for a possible weakening of the substantial (and costly) economic incentives to adopt zero-emission vehicles. Alternatively, continued strong policy incentives could yield a complete transformation to zero-emissions urban mobility based on non-motorized mobility (i.e., walking and cycling), electrified public transport, and electric vehicles.

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Transitions to New Technologies Program

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Food security in a changing world

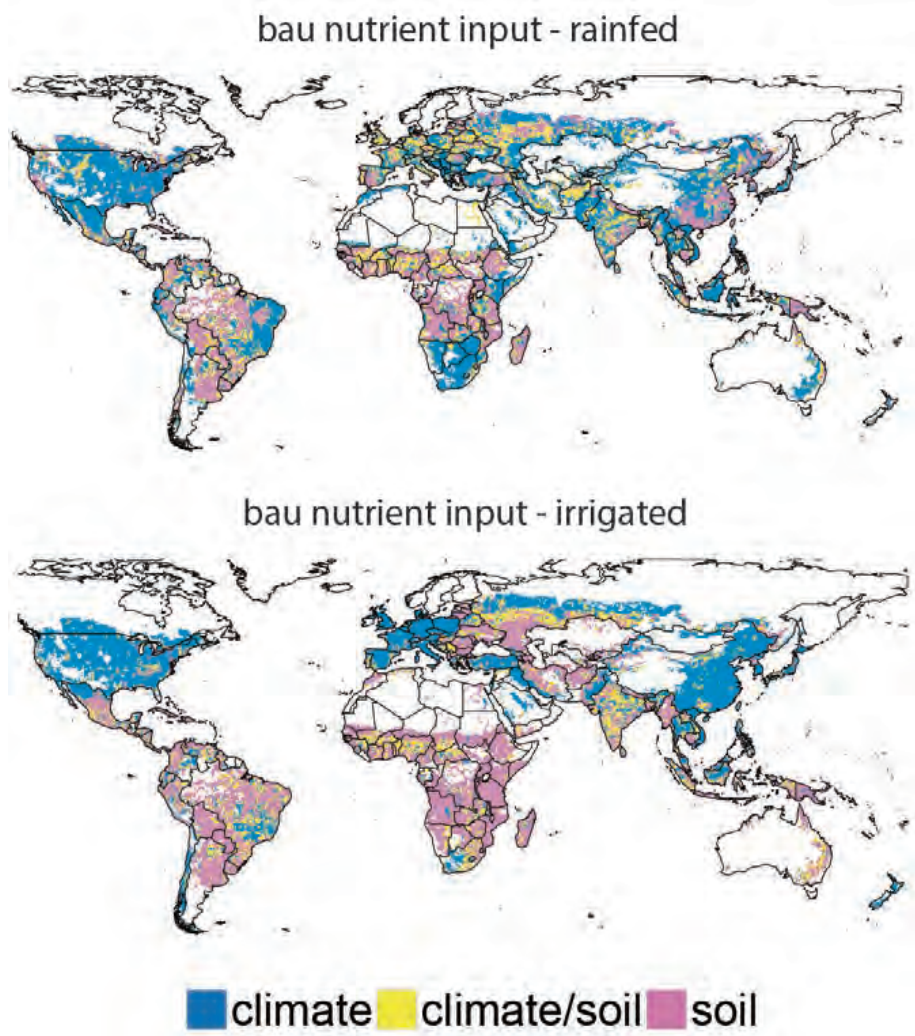
As the population increases and climate change progresses, food security is becoming a pressing issue around the world. To help tackle the challenges we face, IIASA researchers have used agricultural models that estimate how much of a crop can be produced in a certain amount of space. Along with investigating the effects of agricultural intensification, the team also demonstrated the pressing need for better soil data to help improve projections of future crop yields.

To examine how food security might change around the world, the IIASA Ecosystem Services and Management Program used its Environmental Policy Integrated Model to examine how agricultural intensification will affect the productivity of the world's main crops as well as its environmental effects, such as changes to the levels of nutrients, water, and organic carbon stored in the soil. In turn, this research was used to inform another of the program's integrated models, the Global Biosphere Management Model, which is used to analyze the competition for land use between agriculture, forestry, and bioenergy.

In further work, carried our as part of the Agricultural Model Intercomparison and Improvement Project, the team showed that incorporating accurate data on soil type in such models is vital. The study was the first global assessment of the importance of soils in global crop models and showed that the effects of soil type can often outweigh the effects of weather variability—such as year to year changes in rainfall and temperature [1].

This is because soils have the capacity to amplify or buffer climate impacts, for example through the provision of water during the early stages of a drought. In extreme cases, climate change impacts on yield were either negative or positive depending on the soil type chosen for the simulation, the researchers found. In particular, for yield projections in regions that use little fertilizer or irrigation—often poorer regions with many small farms—crop yield variability related to soil type can be larger than yield variability due to weather. In places where farmers use a large amount of fertilizer, the impact of soil type was smaller.

In addition, global crop models often do not include soil management for climate resilience, nutrient management, or erosion control, all factors that can affect yield. Better soil data could therefore substantially improve projections of future crop yields, the researchers conclude.



Grid cells in which climate or soils dominate maize yield variability assuming business-as-usual fertilization, and rainfed (top) and irrigated (bottom) production systems.

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Ecosystem Services and Management Program

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- Potsdam Institute for Climate Impacts Research, Germany
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Sustainable consumption and economic growth

Human exploitation of the Earth's resources is fast approaching planetary boundaries, and the closer we get, the greater the effects on human wellbeing. To aid the transition to a more sustainable path, the IIASA Advanced Systems Analysis Program is developing economic growth models, which inform green growth solutions.

New economic models, now urgently needed, must take into consideration inherent uncertainties and nonlinear effects that change over time. In the search for green growth solutions, IIASA researchers and collaborators have furthered the theory of optimal control for infinite-horizon problems, addressing classes of problems that are typical for economic applications, in which traditional methods fail to deliver rigorous solutions [1][2].

The researchers examined some classes of optimal control problems, which are subject to the Pontryagin maximum principle, working to generalize them over infinite time horizons with unbounded controls [1]. They were able to derive sufficient conditions for the existence of an optimal control, as well as conditions guaranteeing the uniform local boundedness of optimal controls in a general, nonlinear case. In a further study, the team derived the necessary first-order optimality conditions of Pontryagin's type for a general class of discrete-time optimal control problems on an infinite horizon.

To explore how renewable resources can be exploited sustainably, IIASA researchers considered a model of a logistically growing renewable resource. By applying the optimal control theory, they found that a consumption-based utility can increase or stay constant with the resource stock asymptotically non-vanishing only when the resource growth rate is higher than the difference between the discount factor and the technology growth rate adjusted to the elasticity of the production with respect to the resource [3].

To investigate the trade-off between consumption today and investment in the future, given the limited available natural resources, IIASA researchers used the Dasgupta-Heal-Solow-Stiglitz model. They showed that an optimal admissible policy may not exist if the output elasticity of the resource equals 1. In this case, an optimal solution does not exist for a sufficiently small initial stock of produced capital. This implies that it is impossible to formulate a welfare-maximizing policy at an early stage of economic development when produced capital is scarce and resources are abundant. An initial jump to the minimal stock of produced capital is therefore needed, followed by an optimal policy. The researchers characterized the optimal policies by applying a version of the Pontryagin maximum principle for infinite-horizon optimal control problems [4].

Advanced Systems Analysis Program

IIASA researchers also examined the effects of land ownership structures on population growth. Using a family-optimization model, where relative per capita wealth generates social status and wellbeing, they demonstrated that tenant farming is a major obstacle to escaping the Malthusian trap—a situation where technological advances that increase society's supply of resources do not lead to an increase in standards of living because the population simply grows faster in response. Land ownership reform provides farmers with higher returns for their investments, encouraging them to increase their productivity and status rather than their family size. Consequently, the population growth rate slows down, and the productivity of land increases [5].

Population growth can also be influenced by efforts to shift production away from polluting industries, a new study found. IIASA researchers modeled an economy where output is produced by two sectors, dirty and clean. An air pollution emissions tax curbs dirty production, which decreases pollution-induced mortality and shifts resources to the clean sector. If the dirty sector is more capital intensive (i.e., requiring a lot of physical capital—such as machines or other equipment—but not so much labor) the results show that this shift increases labor demand and wages. This, in turn, means that rearing a child is more costly because of the wages one would lose (known as the opportunity cost); this therefore decreases fertility and hence the population size. Correspondingly, if the clean sector is more capital intensive, then the emission tax decreases wages and increases fertility. Although the proportion of production from the dirty sector falls, the expansion of population boosts total pollution, aggravating environmental mortality [6].

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Adopting sustainable technologies: New methods for a new world

The transition to a sustainable energy system will require profound changes across almost every aspect of society, from individual choices to government policies. To aid this transition the IIASA Energy Program (ENE) has worked to enhance global energy-economy models, providing insights into the investments needed to deploy a large share of wind and solar technologies in power systems, and the role of consumer preferences in adopting sustainable transport.

Renewable energy technologies such as wind turbines and solar photovoltaics are deemed essential to creating a sustainable energy system; however, they can be intermittent and it is not possible to adjust their power output to order. This means that power systems with significant deployment of this "variable renewable energy" will likely need more backup capacity to ensure peak demand, more flexibility to address increased fluctuations in power supply, and more energy storage or power-to-gas technology to absorb the excess energy generated at times.

The costs of implementing these changes may be significant, and assessments of low-carbon futures must account for them. However, global energy-economy models are not detailed enough to directly assess impacts due to mismatches between electricity supply and demand that can occur from one minute to the next. To address this, ENE researchers used the Model for Energy Supply Strategy Alternatives and their General Environmental Impact (MESSAGE) to simulate the impacts and costs of the integration of variable renewable energy, providing estimates of the magnitude and duration of the load that must be provided by technologies that *can* adjust their power output to order.

The model indicates that there will be a significant reduction in the use of non-renewable power plants with a diminishing role for traditional generators, such as nuclear and coal, and a transition to more flexible technologies. The results also highlight the importance of electricity storage and hydrogen electrolysis in deploying variable renewable energy. Despite better representation of integration impacts and costs, wind and solar technologies remain competitive with other low-carbon options and climate change mitigation drives the share of variable renewable energy technologies to 53-89% of electricity generation in 2100 across the models [2][3].

ENE researchers have also examined the adoption of sustainable technologies in the transport sector, which is responsible for about a quarter of all energy-related CO_2 emissions. Widespread substitution of conventional vehicles with those powered by low-carbon sources of electricity or hydrogen is seen as essential to limit global warming to 2°C. One critical determinant for this transition will be the consumer preferences for which cars to use.

Again, global energy-economy models fall somewhat short here, as they are limited in their representation of consumer decision-making. To improve the situation, ENE researchers led the first global model comparison exercise to date dedicated exclusively to realistically representing consumer behavior in long-term energy transitions.

Their findings emphasize two key points. First, strategies and policies explicitly targeting consumer attitudes toward alternative fuel vehicles are necessary to drive widespread adoption of these technologies; and second, carbon pricing is needed to ensure that the electricity and hydrogen used to power these vehicles are derived from low-carbon sources [4].

In addition to this work, ENE has taken a leading role in scaling up the International Transport and Energy Modeling Consortium, a group of global transportation modelers and analysts from academia, government, industry, and non-governmental organizations. ENE co-organized the consortium's second workshop in 2016 and preliminary results were presented at UN Climate Change Conference COP22 in Marrakech.

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Building a sustainable future

The world is at a cross roads, and finding a path to sustainable development will require the solution-oriented, systems approach that is the basis of IIASA research.

Selected highlights

Who are the refugees?

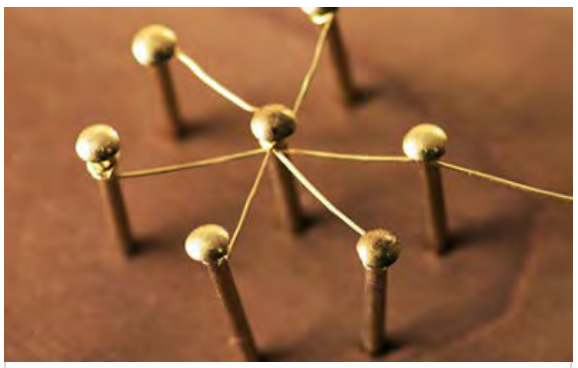
Resilience of the global trade networks

Facing climate change in West Africa

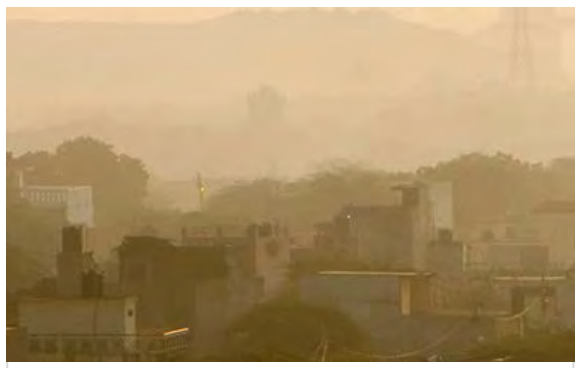
Reducing water stress worldwide

Tackling the nitrogen challenge

Smart policies for sustainability



Reducing the risk of financial crisis



Think outside the city to manage urban pollution

Sustainable Development Goals lead to lower population growth

Negotiating climate loss and damage

Modeling disease eradication

Participatory mapping to enhance disaster resilience

Using carbon markets to tackle climate change and protect forests

Humanity's shared resources

Education matters for all Sustainable Development Goals

Protecting fisheries from evolutionary change

Energy and the Sustainable Development Goals

Health, wellbeing, and aging in the Arctic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Who are the refugees?

In the first study of its kind, IIASA researchers assessed the skills, attitudes, and values of asylum seekers and refugees, showing that those who entered Austria in the summer and fall of 2015—especially those from Syria and Iraq—are fairly well educated, have rather liberal values, and come from predominantly middle-class backgrounds.

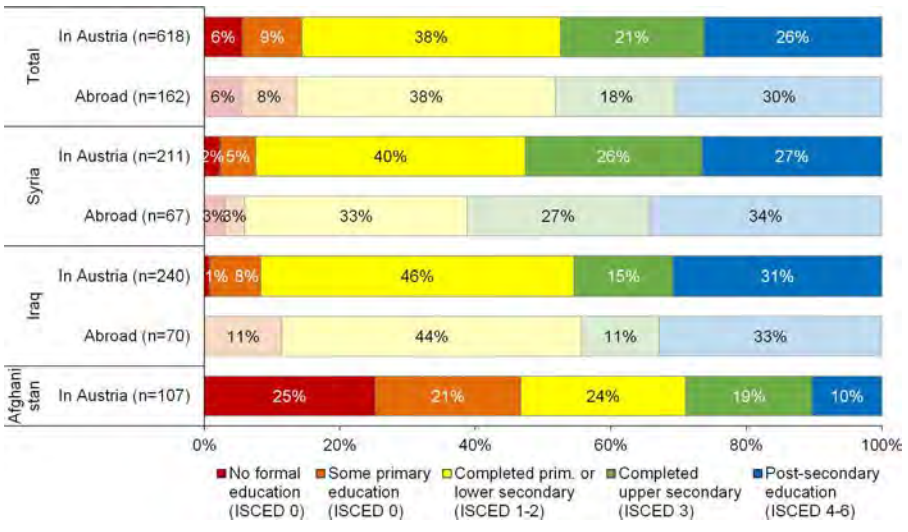
To assess the integration potential of refugees, it is important to learn about their education, professional qualifications, attitudes, and hopes for the future. The new study from the Vienna Institute of Demography and IIASA World Population Program investigated these features for the first time in a German-speaking country.

Contrary to the widely held views that asylum seekers and refugees are uneducated, the study showed that almost half of the respondents from Syria and Iraq had completed secondary education, and more than a quarter had at least obtained a post-secondary degree, such as a high-school diploma or a higher education degree. This is roughly the same as the percentage of people with post-secondary education currently resident in Austria, according to the research team.

For the study, which was published in the internationally renowned journal *PLOS ONE,* a team of researchers surveyed 514 asylum seekers and refugees from both sexes and different ages, mainly from Syria, Iraq, and Afghanistan, in November and December 2015, leading to a sample of around 1,400 people. Face-to-face interviews were conducted to question respondents about their origins, education, professional experience, marital status, attitudes, values, and future plans.

The high level of education is reflected in the values and attitudes of the respondents, who overall view themselves as not particularly traditionally oriented. Asylum seekers and refugees in Austria consistently identified themselves as more liberal than the population in their home countries, assessed using the "World Values Survey," which investigates attitudes on issues such as religion and gender relations in Arab countries. Nearly a quarter of the respondents declared themselves not to be religious at all, and a significant majority of the surveyed men and women agreed with the statement that "having a job is the best way for a woman to be an independent person."

The researchers hope that these results will contribute scientific facts to the public debate about the integration of asylum seekers and refugees. According to World Population Program Director Wolfgang Lutz, the study implies that "the potential for integration of refugees who came to Austria last year is encouraging: high education levels, rather liberal attitudes, and a firm affiliation with the middle classes of their respective countries of origin are good conditions for fostering successful integration into European societies."



Educational attainment of asylum seekers surveyed and their spouses and adult children in Austria (saturated colors) and abroad (pale colors), 20–59 age group. Source: DiPAS

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World Population Program

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Further information

On the blog: Why are the refugees who came to Austria in 2015 more educated than expected?

Resilience of the global trade networks

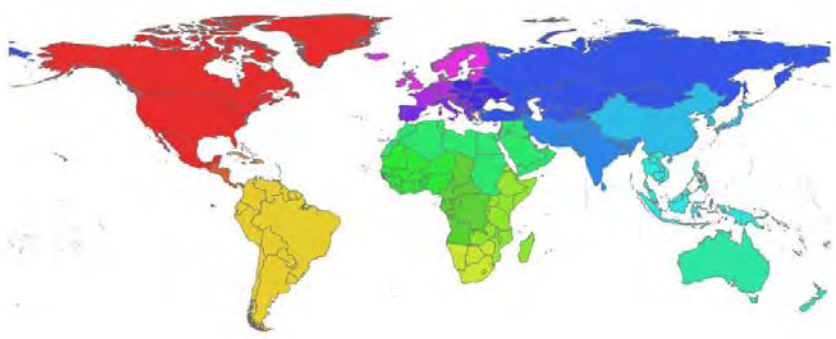
Today's supply chains extend across the world and trade is a truly global phenomenon. It is therefore an issue of national security for every country to ensure the sustainability of their exports and imports. To help tackle this, IIASA researchers have analyzed key trade networks related to food and energy security, and examined their resilience and function.

Seafood plays an important role in food security, making up nearly 20% of animal protein consumption around the world. At the same time, seafood supplies are vulnerable to natural disasters, fishery collapses, policy changes, and price spikes in fossil fuels.

To examine how seafood trade might be affected by such shocks, researchers from the IIASA Advanced Systems Analysis and Evolution and Ecology programs developed a shock-propagation global trade network model. The results show that Central and West Africa are the most vulnerable to shocks. In addition, if such an event did occur, richer regions might be more willing to prioritize their domestic consumption, which would pass on the shock to other regions in the trade network. If this is taken into account in the model, the researchers found, Central and West Africa are even more at risk.

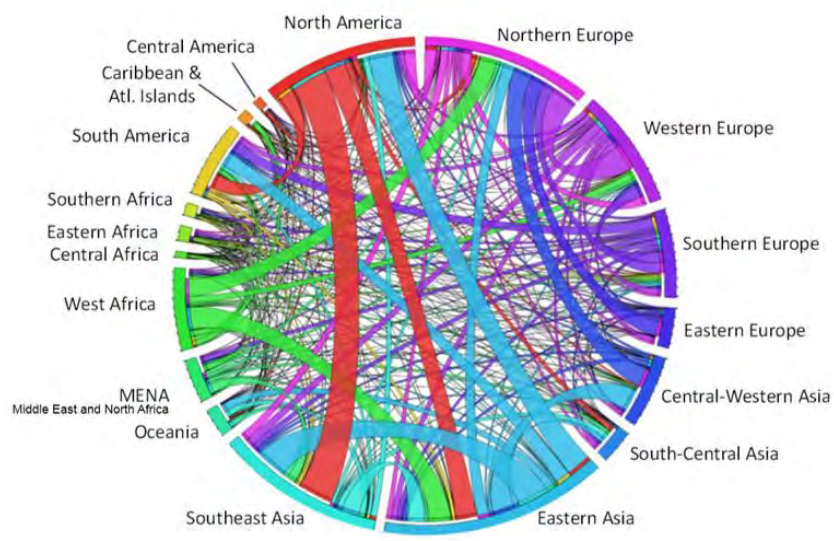
These findings suggest that countries can reduce their overall vulnerability to shocks by reducing reliance on imports and diversifying food sources. As international seafood trade grows, identifying these types of potential risks and vulnerabilities is important to build a more resilient food system [1].

Another important factor to take into account in trade networks is "non-market forces"—such as preferential trading agreements between countries that are not related to supply and demand. To reveal these non-market forces in trade networks, IIASA researchers developed a diagnostic tool and tested it on the oil trade—one of the most important networks in the global economy.



By analyzing the historical trends in oil trade, the researchers determined the pairwise trade preferences and dependencies using a point-wise mutual information method. This approach compares the actual reality of the trade network with a 'neutral' model, in which bilateral trade is purely determined by each country's supply and demand constraints.

For example, using the tool, the team demonstrated that actual amount of oil imported from Canada to USA was seven times larger than suggested by the demand-supply based neutral model. This can be attributed to the non-market impacts of geographical proximity and some preferentiality [2].



Global seafood trade among world regions. A band's width represents the traded biomass and a band's color represents the importing region. The new study assesses the vulnerability of world regions to supply shocks in this trade network.

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Advanced Systems Analysis Program

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Facing climate change in West Africa

Climate change is likely to hit West Africa hard, potentially affecting the livelihoods of millions of people. The IIASA Ecosystems Services and Management Program has worked closely with local stakeholders to develop possible climate strategies, showing that low investment in agriculture will leave the region particularly vulnerable.

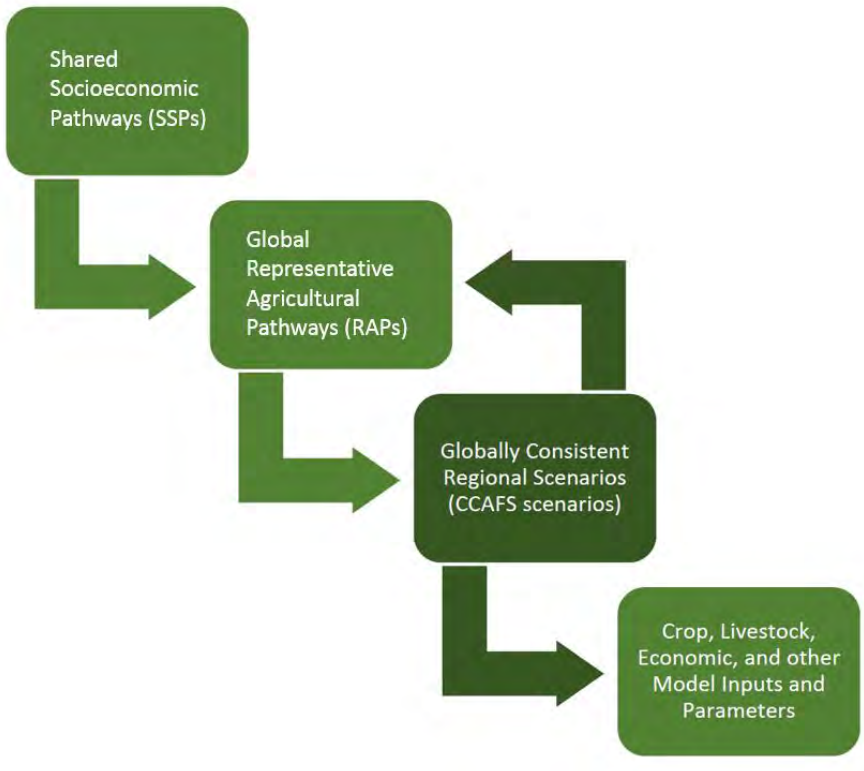
West Africa is a major producer of crops such as cassava, millet, and sorghum but climate change could mean regional production is not able to meet the growing demand for food and livestock feed. To help policymakers develop robust climate strategies, IIASA researchers built scenarios, or future pathways, and applied the institute's Global Biosphere Management Model alongside the International Model for Policy Analysis of Agricultural Commodities and Trade developed by the International Food Policy Research Institute [1].

The results show that investments in agriculture in the region, specifically to improve crop yields, could lead to greater food production. However, it could also create land trade-offs: agricultural expansion in West Africa will encroach into forest and other natural land, but it will also reduce the need for agricultural land globally. In some cases, for each hectare of land converted to agriculture in the region three times as much land could be spared in other areas [2].

To develop the scenarios for the work, the team worked closely with local experts to develop plausible futures for the region. Then they linked the scenarios with the new global socioeconomic projections developed for climate change research—the Shared Socioeconomic Pathways [3] —and adapted them to provide specific information for West Africa. This resulted in the first globally coherent, regionally relevant Representative Agricultural Pathways.

In order to create scenarios that would be useful for regional planning, the researchers conducted extensive meetings with policymakers, farmers, and other stakeholders to gain an understanding of the many factors driving agricultural production in the region.

The study resulted in a package of scenarios specifically designed for West Africa to the year 2050, which include climate change as an unavoidable outside force. The scenarios provide descriptions of potential future developments, including narratives as well as quantitative projections for factors such as population, economic growth, deforestation, land use, food production, and trade.



Globally consistent regional scenarios.

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Ecosystem Services and Management Program

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Reducing water stress worldwide

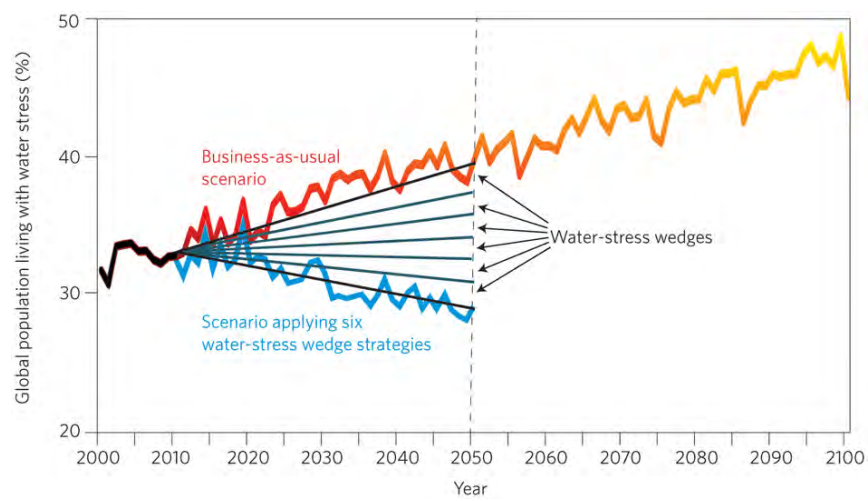
IIASA researchers have identified six water management strategies that can help reduce water stress. Implementing all six strategies, which include increased water recycling and improved irrigation techniques, would reduce the population living with water stress by 12% by 2050.

Water scarcity is not just a problem for the developing world [1]. In California, USA, legislators are currently proposing a US$7.5 billion emergency water plan to their voters; and the US federal officials warned residents of Arizona and Nevada in 2016 that they could face cuts in Colorado River water deliveries. Climate change, wasteful irrigation techniques and industrial and domestic demand lie at the root of the problem, and if current trends continue, water demand would more than double by the year 2050 [2][3][4]. But despite what appears to be an insurmountable problem, it is possible to turn the situation around and significantly reduce water scarcity in just over 35 years, IIASA research has found.

"Water stress" is a term used to describe a situation where more than 40% of the water from the rivers in an area is unavailable because it is already being used [5][6]. Currently, about a third of the global population is affected, and as many as half the people in the world may be coping with water stress by the end of the century, if the current pattern of water use continues [7][8]. Researchers from the IIASA Water Program and their collaborators have outlined six key strategies that they believe can be combined in different ways in different parts of the world to effectively reduce water stress.

The six strategies can be divided into either "hard-path" measures, involving building more reservoirs and increasing sea water desalination, or "soft -path" measures that focus on reducing water demand rather than increasing water supply. These latter often work via community-scale efforts and decision-making, and include improving irrigation efficiency and industrial water use. While there are some economic, cultural, and social factors that may make certain soft-path measures difficult, such as population control, in general the soft path offers a more realistic way forward in terms of reducing water stress.

There is no single silver bullet to deal with the problem around the world. However, by looking at the problem on a global scale, the researchers calculated that if four of these strategies were applied at the same time the number of people in the world who are facing water stress would stabilize rather than continue to grow, which is what will happen if we continue with business as usual. Significant reductions in the number of people suffering water stress are possible by 2050, but a strong commitment and strategic efforts are required to make this happen.



The impact of strategies for reducing global water stress. The six strategies, or water-stress wedges, collectively lead to a reduction in the population affected by water stress by 2050, despite an increasing population. For simplicity, the water-stress wedges are shown here as straight lines, although the proposed efforts are unlikely to produce such consistent and linear results. The climatic variability of precipitation is included in the colored lines, whereas the water-stress wedges are simplified straight-line projections.

Water Program

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Further information

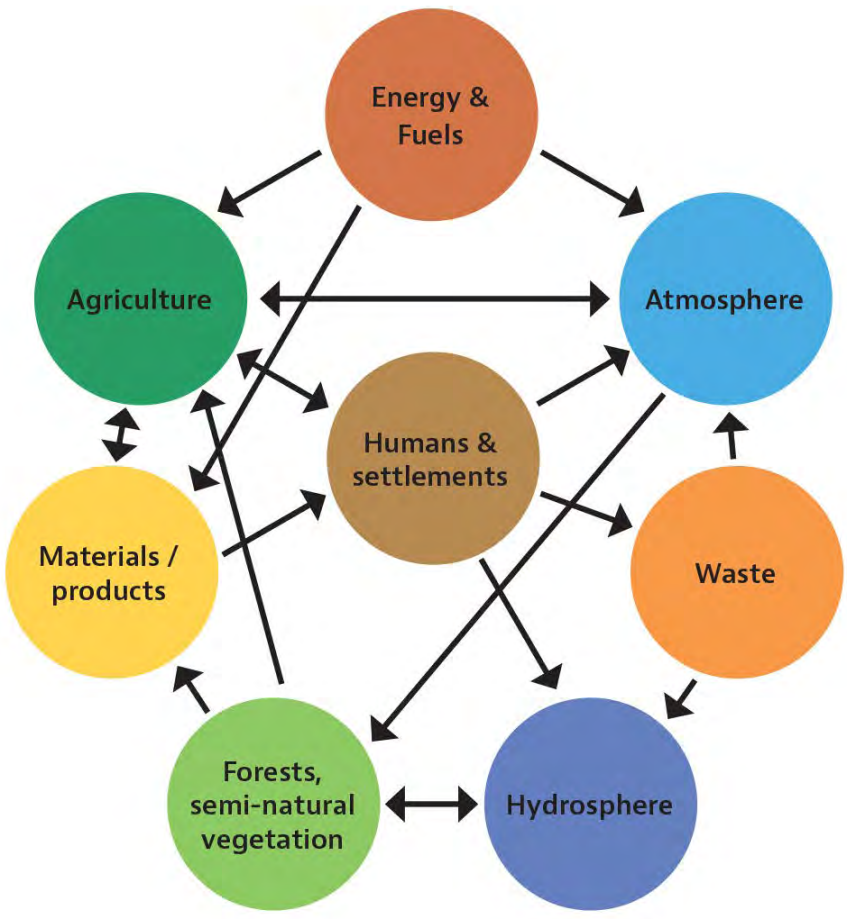
Changing rainfall patterns linked to water security in India

Tackling the nitrogen challenge

Minimizing the environmental damage caused by nitrogen fertilizer while maximizing food production is known as the "nitrogen challenge." To help countries face this challenge, IIASA researchers have developed consistent, comprehensive guidance on creating national nitrogen budgets. Based on a systems approach, the guidance helps avoid trade-offs and allows countries to compare performances and share best practices.

While nitrogen compounds are a crucial part of growing our food, they are also responsible for severe environmental consequences, from air and water pollution, to global warming and biodiversity decline. Human activities have had significant impacts on the global nitrogen cycle, and we have already exceeded the "planetary boundary" for nitrogen—a tipping point that brings the risk of irreversible and abrupt environmental change.

The IIASA Air Quality and Greenhouse Gases Program has taken a systems approach to the "nitrogen challenge," quantifying nitrogen flow and identifying possible interventions to reduce environmental impacts while retaining agricultural productivity.



The concept of environmental stocks (circles) and major flows (arrows) of nitrogen compounds used for the National Nitrogen Budgets Guidance Document.

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Researchers from the program led an international team to develop the National Nitrogen Budgets Guidance Document—specific guidance for European countries on how to use their available data for nitrogen budgets.

The approach could form the foundation of an International Nitrogen Management System, applied to countries around the world. At the same time, researchers are also working to extend the concept to individual farms, to give local, small-scale coverage.

The researchers used a framework made up of stocks and flows, which accounts for all nitrogen as it moves though the entire system. This approach minimizes the chances of unforeseen trade-offs; a solution drawing nitrogen out of the air, for example, is no good if it ends up polluting the rivers.

Using the generic rules of the guidance document and nitrogen data specific to their country, national experts can create accurate nitrogen budgets and assess flows. Comparing flow estimates allows users to validate information, and supplement missing data. For instance, if you know how much nitrogen fertilizer went on to the field and how much stayed in the soil and was taken up by plants, then you can deduce how much was lost to the rivers.

The approach allows countries to compare performances and share best practices, and forms the backbone of intervention planning to reduce nitrogen pollution across the system.

IIASA researchers have used the approach to examine nitrogen flows in non-food industrial products (polymers, wood and paper products, waste), and nitrogen related to pets, gardens, and energy use [1]. The team has also used the framework to assess the costs of measures aimed at reducing nitrogen emissions from livestock production via new feeding strategies [2].

The guidance document is fully compatible with existing reporting guidelines, specifically regarding countries' obligations to the UN Framework Convention on Climate Change, the UN Economic Commission for Europe (UNECE), and Eurostat. It has also been adopted by the UNECE Convention on Long Range Transboundary Air Pollution, and was specifically referred to in a 2016 EU Directive on atmospheric pollutants.

The approach could form the foundation of an International Nitrogen Management System, applied to countries around the world. At the same time, researchers are also working to extend the concept to individual farms, to give local, small-scale coverage.

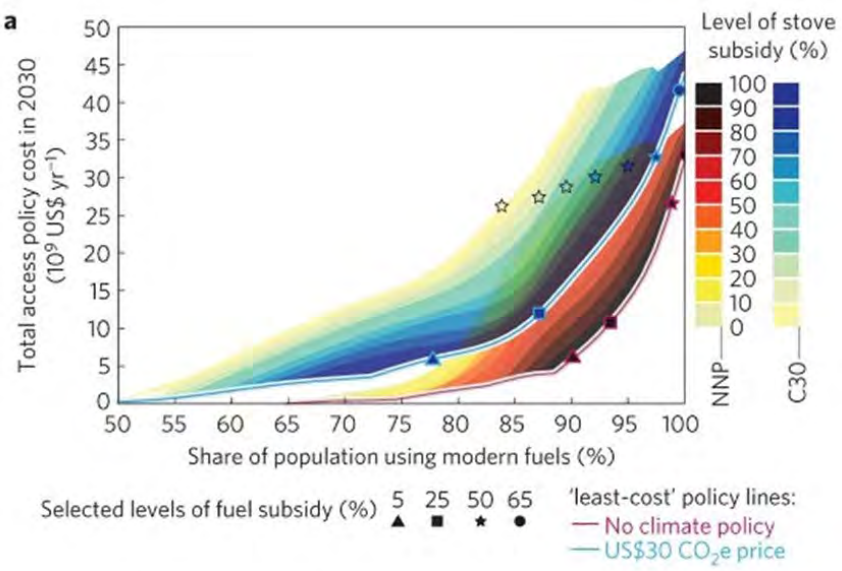
Air Quality and Greenhouse Gases Program

Smart policies for sustainability

Effective climate policy is a vital sustainability goal but it must also be balanced against improving energy access and reducing poverty. For instance, unless they are carefully designed, new climate policies in Asia could push access to modern energy out of reach for millions in the region, research from the IIASA Energy Program (ENE) has found. The team also examined how eliminating poverty will affect energy use and greenhouse gas (GHG) emissions.

The Sustainable Development Goals aim to achieve universal access to modern energy by 2030—but they also call for urgent action to combat climate change. An ENE study focused on this issue in South Asia, where 72% of the population relies on solid fuels for cooking—causing air pollution and related health problems. It showed that by 2030 that could be reduced to 35% on the current trajectory. But with climate policies and no energy access policies, 336 million people would be unable to afford the switch modern fuels [1].

A further study examined kerosene subsidies, initially designed to help those without electricity but now hampering the shift to clean energy. In India 64% of kerosene used for lighting is supplementary to electricity, the research showed, which means that simply increasing electricity access without improving reliability will only reduce the kerosene used by a small amount [2]. Instead, eliminating subsidies by 2030 could reduce kerosene use by 97%, and would also benefit the economy, since the deadweight loss—a measure of economic inefficiency—of the subsidy is US$200–950 million. The solution, the researchers say, is to shift subsides towards improving electricity reliability and cleaner lighting technologies.



Energy access policy cost-effectiveness under baseline and climate mitigation scenarios [1].

Addressing energy access, however, is only a first step in combating energy poverty. The *Decent Living Energy* project goes beyond energy access and aims to quantify the energy needs and related climate change impacts of eradicating poverty and providing decent living standards to all.

Under the project, ENE researchers clearly defined for the first time the material requirements needed for human wellbeing. These include things in the home, such as food and cooking equipment, but also extend to societal level, including the infrastructure needed, such as roads. The definition helps policymakers set fair wages and quantify environmental impact [3].

To understand how eliminating poverty will affect energy use and GHG emissions, researchers also examined how household consumption and energy use increases with rising income.

One study examined what makes people more likely to own household technologies like washing machines, which use a lot of electricity. Examining data from IIASA member countries Brazil, India, and South Africa, they found that the appliances people buy depend not only on their income, but also factors such as race, culture, and wealth in terms of assets like cars, which can secure loans when income alone cannot [4]. A second analysis, using carbon footprinting for Brazilian and Indian households, revealed that the amount of energy used through consumption is largely constant across income groups. This challenges conventional wisdom that poverty eradication would cause a large increase in emissions [5].

Finally, the team investigated how living standards rise with economic growth. As incomes increase in developing countries, access to amenities such as electricity, clean cooking energy, water, and sanitation also improves but not uniformly, and not as quickly as income growth [6][7]. Access to clean cooking energy and sanitation lagged behind access to electricity and water, a finding which has an outsize impact on the poorest, especially women.

Energy Program

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- Research for the Nature Energy article was done with funding support from the project *Advanced Model Development and Validation for Improved Analysis of Costs and Impacts of Mitigation Policies*.
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Further information

MESSAGE-Access model

Reducing the risk of financial crisis

A financial crisis can start with the collapse of a single bank. As other institutions with financial links to the bank also get into trouble, a cascade of failures begins across the whole system, potentially leading to a global crisis. IIASA researchers have been working to reduce this "systemic risk."

Today, financial institutions around the world are becoming increasingly inter-dependent. As a result, the actions and interactions of individual organizations, even if small, can catalyze significant cascading effects, leaving the whole system susceptible to profound systemic risk.

As part of the cross-cutting IIASA project *Systemic Risk and Network Dynamics*, which also involves the institute's Evolution and Ecology and Risk and Resilience programs, researchers from the Advanced Systems Analysis Program have developed new approaches to modeling network dynamics and to assessing and managing systemic risk using agent-based modeling and game theory.

In recent work, IIASA researchers proposed a potential method—a "systemic risk tax"—to encourage the financial network to self-organize to reduce risk. This tax on individual transactions between financial institutions would be based on the level of systemic risk that each transaction adds to the system—and could essentially eliminate the risk of collapse of the financial system [1].

A further study on this topic used an equilibrium concept inspired by the matching markets literature, and showed that in addition to allowing a regulator to effectively "rewire" the interbank network so as to make it more resilient, a systemic risk tax also does so without sacrificing transaction volume [2].

An alternative way to mitigate systemic risk is to use credit default swaps. These are agreements where the seller will compensate the buyer in the event of a loan default by the third party debtor. Since these transfer the default risk from one bank to another, a market for credit default swaps can be designed to rewire the network of interbank exposures in a way that makes it more resilient to insolvency cascades. This works in a similar way to the systemic risk tax [1], by effectively taxing the credit default swaps based on the level of systemic risk that they add to the system. This makes the entire network more resilient to domino effects [3].

Reducing financial systemic risk is also the aim of the third Basel Accord—a global, voluntary regulatory framework on bank capital adequacy, stress testing, and market risk. However, the accord as planned will not reduce systemic risk in a substantial way, IIASA research, using an agent-based model, has found [4].

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Advanced Systems Analysis Program

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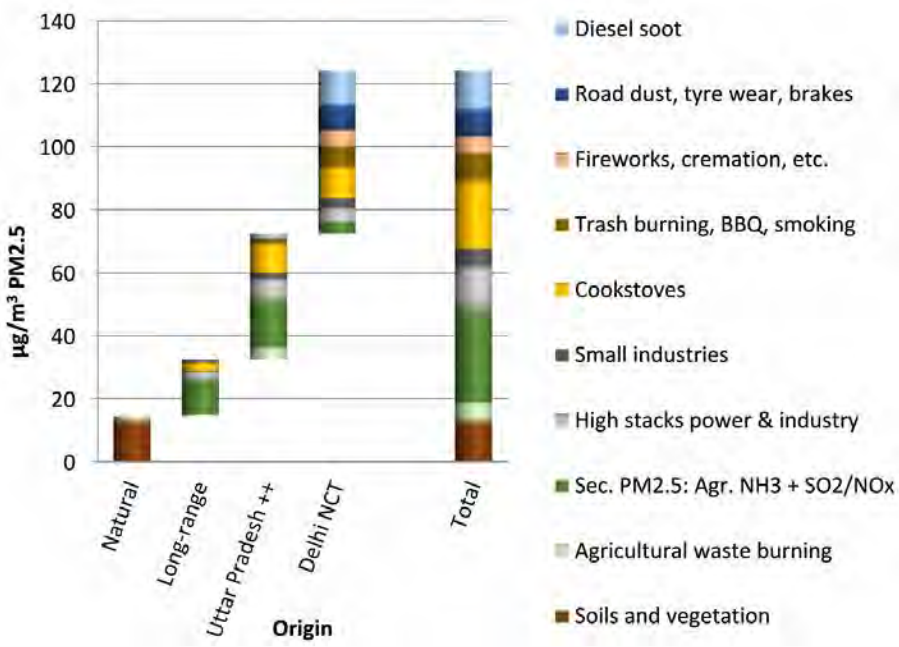
Think outside the city to manage urban pollution

Only around 40% of the fine particulate matter pollution in Delhi originates from within the city, and about 60% percent is transported from outside, an IIASA study found. This illustrates the problem with focusing on urban areas when looking for solutions to air pollution. To address this, the IIASA Air Quality and Greenhouse Gases Program (AIR) has developed a blueprint for managing air pollution in fast-growing megacities in developing countries, showing that effective solutions require regional and multi-sectoral cooperation.

As most people live in cities, air pollution is widely considered an urban problem, and traditionally solutions are sought at the urban level. However, air pollution can travel over long distances, and conventional solutions that deal with air pollution on a local level, such as policy responses by city administrations, cannot deliver effective solutions.



Contributions from different sources to population exposure to PM2.5 in Delhi, 2015. Uttar Pradesh is an Indian state that borders Delhi NCT (the National Capital Territory of Delhi).

In a joint project with the Indian Institute for Environmental Engineering Research, AIR used its Delhi -specific Greenhouse Gas – Air Pollution Interactions and Synergies model (GAINS-Delhi) to explore management options that could efficiently improve air quality in the city, with a focus on fine particulate matter pollution ($PM_{2.5}$). The work also provides a blueprint for managing air pollution in other fast-growing megacities in developing countries.

Despite the large size of Delhi, currently about 18 million inhabitants, only around 40% of the $PM_{2.5}$ the population is exposed to originates from local emissions, about 60% percent is transported into the city from outside, the study found. Contrary to widespread belief, traffic contributes only about 15-20% of the $PM_{2.5}$ the population is exposed to. In fact, the majority originates from a combination of other sources, including households, small-scale industries and workshops, trash burning, agriculture, and fireworks.

Recent regulations to control emissions from large individual sources in the surrounding areas should stabilize the pollution coming into the city, the researchers found. However, the decline in particulate matter in exhaust gas as a result of new traffic standards in Delhi is likely to be negated by non-exhaust emissions—such as road dust, and tire and brake wear—that will increase along with the expected growth in traffic volumes. The anticipated economic growth is also likely to counteract the benefits of the ambitious pollution control measures adopted by the authorities. As a consequence, the researchers conclude, air quality will continue to deteriorate.

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Air Quality and Greenhouse Gases Program

Collaborators

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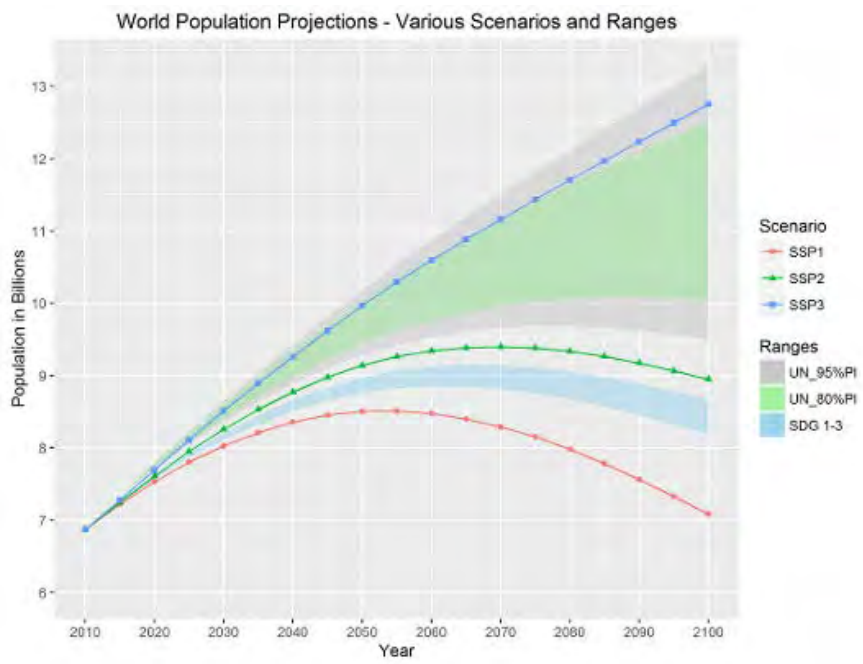
Sustainable Development Goals lead to lower population growth

Achieving the Sustainable Development Goals would significantly slow population growth, a landmark study from the IIASA World Population Program shows.

Achieving the Sustainable Development Goals (SDGs) set by the UN in 2015 for the period up to 2030 would lead to a global population of between 8.2 to 8.7 billion by 2100, according to a new study conducted by IIASA and the Asian Demographic Research Institute at Shanghai University. According to the study, published in the journal *Proceedings of the National Academy of Sciences*, achieving the SDGs would lead to population growth below even the lower bound of recent UN probabilistic population projections.

The SDGs include 17 goals with 169 different targets, aimed at fighting poverty, reducing inequality, and addressing climate change, while leaving nobody behind. They include goals such as quality primary and secondary education for all children, gender equality, and reduced child mortality, which all have direct and indirect impacts on population growth.



The IIASA projections assess three different scenarios for the implementation of the SDGs, focusing on the goals that could impact fertility and mortality rates and thus population growth. Data are freely available on the IIASA website www.iiasa.ac.at/SDGscenarios2016

Although population is not mentioned in any of the 169 SDG targets, many people think it is a decisive factor for global environmental change and future human wellbeing. The study is the first to assess how successful implementation of the SDGs would affect population growth. Assuming that for the period 2015-2030 the goals will serve as a turbo boost for development, it finds that achieving the SDGs would lead to global population peaking by 2060, and declining to between 8.2 and 8.7 billion by 2100.

The effects of increasing female education on lowering birth rates in developing countries, and the health target that includes universal access to reproductive health services are the key factors. Achieving these two goals, the study showed, would lead to reduced fertility rates in much of the developing world. The researchers note that achieving the SDGs would also lead to reduced mortality, which would tend to increase population, but that in the longer term, decreased mortality rates also contributes to lower birth rates.

Even if the goals were only partly achieved, the study finds potentially significant decrease in population growth. However, if the international community fails to reach the SDGs then world population growth will be higher, people will be poorer and in worse health, and more vulnerable to environmental change.

The new projections fall outside of the 95% confidence range of 2015 UN probabilistic projections, which range from 9.5 to 13 billion in 2100. The study provides sensitivity analyses of key model assumptions and starting data uncertainty, indicating that the UN projections may have too small a range of uncertainty.

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Yavuz Sariyildiz | Shutterstock

Negotiating climate loss and damage

The Paris climate agreement included groundbreaking text on the need to identify risks beyond adaptation and support the victims of climate-related loss and damage—but how exactly it will work remains unclear. An IIASA paper has laid out a framework to point a way forward in these complex negotiations as well as making suggestions for the next steps in research.

It is widely agreed that many countries will need assistance in responding to climate change—indeed some are already suffering sever impacts—yet there has been a contentious debate between vulnerable countries and developed nations about the extent of such assistance and the form that it should take.

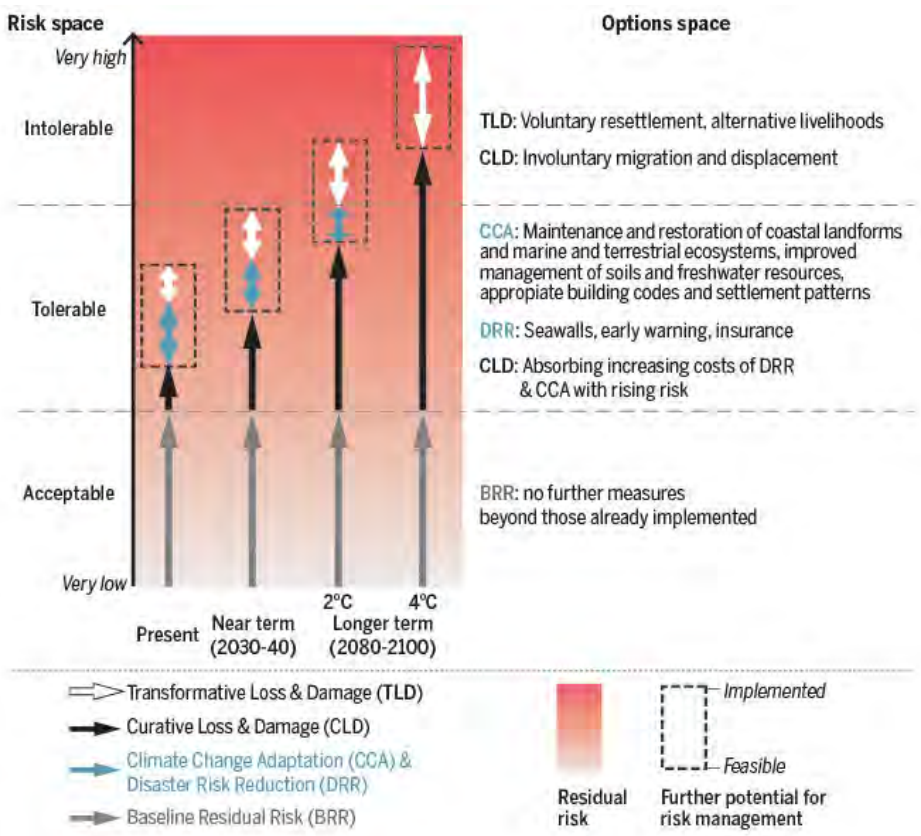
In a paper published in the journal *Science*, researchers from the IIASA Risk and Resilience Program lay out a framework for loss and damage in terms of supporting measures that can help vulnerable people survive, adapt, and even become more resilient in the face of irreversible climate change impacts.

The researchers identify two sets of options where developed and developing countries could agree on international support for coping with loss and damage in addition to support for climate adaptation.

The first set of options refers to support for "curative" measures, which deal with unavoided and unavoidable risks. An example of such measures would be seawalls, needed to cope with rising sea levels caused by climate change. At high levels of warming, impacts become unavoidable, and people may be forced to migrate, for which international legal protection is essential.

The second set of options refers to the concept of transformative risk management—that means building resilience against climate-related impacts while also realizing that people will need support to learn new skills and develop new livelihoods, or even voluntarily migrate to new homes. Transformative risk management goes beyond traditional risk management to enhancing people's resilience more broadly.

In terms of future research, the study concludes that three lines of analysis are of particular importance: (i) ensuring that assessment of climate-related risk is comprehensive; (ii) taking social-science perspective on risk (iii) examining distributive and compensatory justice with regard to burden sharing.



Climate risk management options for small island states. The risk and policy space for Loss and Damage as applied to risks from sea level rise in small island states. The scenarios identify classes of curative measures for unavoided and unavoidable impacts of sea level rise and transformative measures for avoiding and managing increasingly intolerable risks.

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Further information

Informing action on a historic climate agreement

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Modeling disease eradication

Diseases evolve in response to treatment, frustrating efforts to eradicate them. In 2016 the IIASA Evolution and Ecology Program explored how evolution, population dynamics, and economic factors interact, providing new insight that could help inform efforts to control diseases like malaria.

Efforts to eradicate a disease are likely to fail if medical professionals only know the target of an eradication campaign, but cannot predict the course for reaching it, according to IIASA research. The 2016 study examined the interplay between disease evolution, human populations, and economic factors to determine how diseases can be controlled, using a new, model-based view of disease eradication.

Despite many efforts to eliminate specific diseases, there have only been two success stories: smallpox and rinderpest. Most of the world's deadly illnesses have survived repeated efforts to eradicate them, resurging in vulnerable populations and in some cases gaining resistance to standard treatment. Malaria, for instance, infected over 200 million people in 2010, killing around 500,000 according to the World Health Organization.

The problem is that it's easy to make progress at the beginning, but in the last stages of eradication, when there are only a few cases, it becomes very difficult to make further progress.

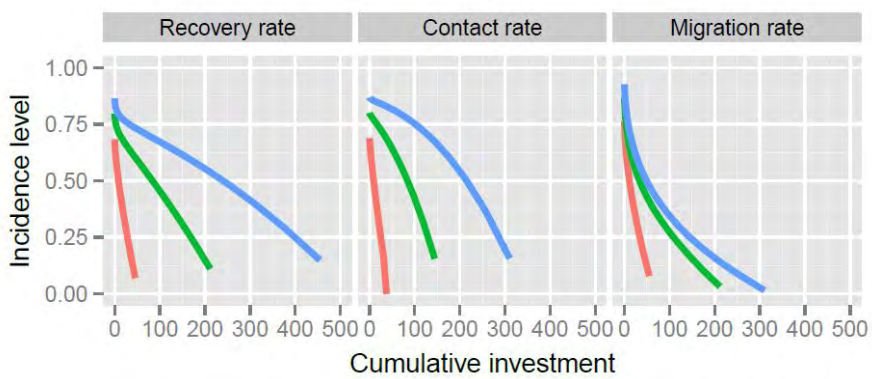
A graph of this process would show a fast decline in the incidence of the disease, which peters out into a long tail that the researchers call an "eradication tail." The reasons for this are multiple. The microbes that cause disease evolve in response to changes in their environment, sometimes gaining resistance to the drugs used against them. Likewise, eradication efforts may target the animal that spreads a disease, such as mosquitoes, which may thus evolve or adapt in response.

Also the way human populations are structured plays a role—since diseases spread between individuals, predicting eradication tails requires mapping a population and links between diseased individuals. And crucially, economic factors contribute as well—if the money for interventions runs out, the disease may come back.

The study examined how much each of these factors affected eradication in a model system. It showed that while all three factors were important, the economic factor played a deciding role in shaping the trajectory of disease eradication.

The researchers found that extending the money and time spent on an eradication campaign can make up for the tendency of evolutionary and population factors to allow a disease to persist. While evolution could allow the disease to develop resistance or become more virulent or deadly, population dynamics could allow the disease to 'hide' in an isolated subset of the population, and spread back to the general population in the future.

Most epidemiology research today has an on-the-ground view of specific disease data. This study shows that a model-based perspective of disease eradication can provide useful information for public health institutions aiming to eradicate diseases.



To reduce an infectious disease's incidence level, health officials need to invest precious resources. As an eradication campaign progresses, these investments have less and less impact, resulting in so-called eradication tails. The shape of these depends on the disease characteristics (colors), as well as on whether the investments help increase the recovery rate of patients from the disease (left panel), decrease the contact rate among healthy and infected patients (middle panel), or restrict the mobility of patients (right panel).

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Evolution and Ecology Program

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Participatory mapping to enhance disaster resilience

To fill critical knowledge gaps in local flood risk information, IIASA has collaborated with practitioners to engage communities in a participatory process to map risk, resources, and capacities in flood-prone areas in Nepal and Peru. The new digital maps contain more information, are more accurate, and are easier to update and share than conventional flood risk maps.

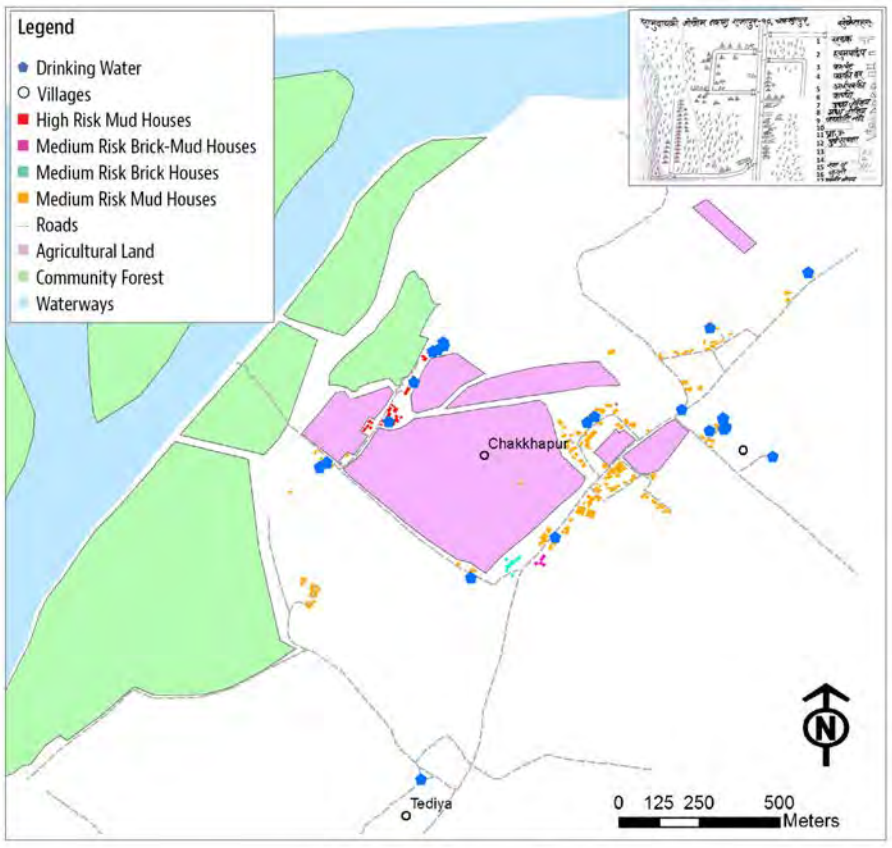
Floods have the largest negative impact of all natural hazards, with about 1.5 billion people worldwide affected since 2000. Reducing risk in flood-prone areas requires a clear understanding of flood risk on the ground. Knowledge of "all dimensions of vulnerability, capacity, exposure of persons and assets, hazard characteristics, and the environment" [1] is needed to inform policies and practices across all stages of the disaster risk management cycle: from pre-disaster risk assessment, to risk prevention and mitigation, to preparedness and effective response.

Critical knowledge gaps seriously hinder efforts to build flood resilience, especially in disaster-prone developing countries. Moreover, information gaps are most serious at local levels, especially in terms of spatial information on risk, resources, and capacities of communities. The recommendation of the Sendai Framework for Disaster Risk Reduction is "to develop, periodically update and disseminate, as appropriate, location-based disaster risk information, including risk maps, to decision makers, the general public and communities at risk of exposure to disaster in an appropriate format by using, as applicable, geospatial information technology" [1].

There is great potential for new technologies to support flood resilience. In addition to existing expert-based data collection and analysis, direct input from communities and citizens across the globe may also be used to monitor, validate, and reduce flood risk. New technologies have already been proven to effectively aid in humanitarian response and recovery. However, while technology is increasingly used to collect information on exposure, efforts directed towards assessing and monitoring hazards and vulnerability remain limited. Hazard model validation and social vulnerability assessments also deserve particular attention.

For this work, researchers from the IIASA Risk and Resilience and Ecosystems Services and Management Programs developed an approach that combines community-based participatory mapping processes with emerging internet-based digital mapping techniques [2]. In collaboration with Practical Action (a UK non-profit organization) and local professionals, IIASA researchers demonstrated the value and potential of this participatory and collaborative digital mapping approach in the flood-prone lower Karnali River basin in western Nepal.

The new digital community maps are richer in content, more accurate, and easier to update and share than those produced using conventional vulnerability and capacity assessments. The process engaged a wide range of stakeholders to generate geographic information on resources, capacities and flood risks of pilot communities based on their local needs. This approach, as an inclusive form of risk knowledge generation, can make important contribution to the understanding of disaster risk and therefore help enhance disaster resilience. The team continues to work with collaborators to map more communities in western Nepal and mountainous Peru [3].



Participatory mapping

Conventional hand-drawn community risk map, capacity map, and social map versus digital community map produced via a participatory and collaborative mapping approach.

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Risk and Resilience Program

Collaborators

- Practical Action and Practical Action Consulting, UK and Nepal.
- International Federation of Red Cross and Red Crescent Societies
- Kathmandu Living Labs, Nepal

Using carbon markets to tackle climate change and protect forests

Under the UN program on Reducing Emissions from Deforestation and Forest Degradation (REDD), forest owners can pledge to protect their forest, and sell those pledges to electricity producers to offset their emissions. A clear indication that the price of carbon emissions will rise in the future, combined with a benefit-sharing mechanism that ensures forest owners will not lose out under rising carbon prices, could increase participation in the scheme, IIASA research has shown.

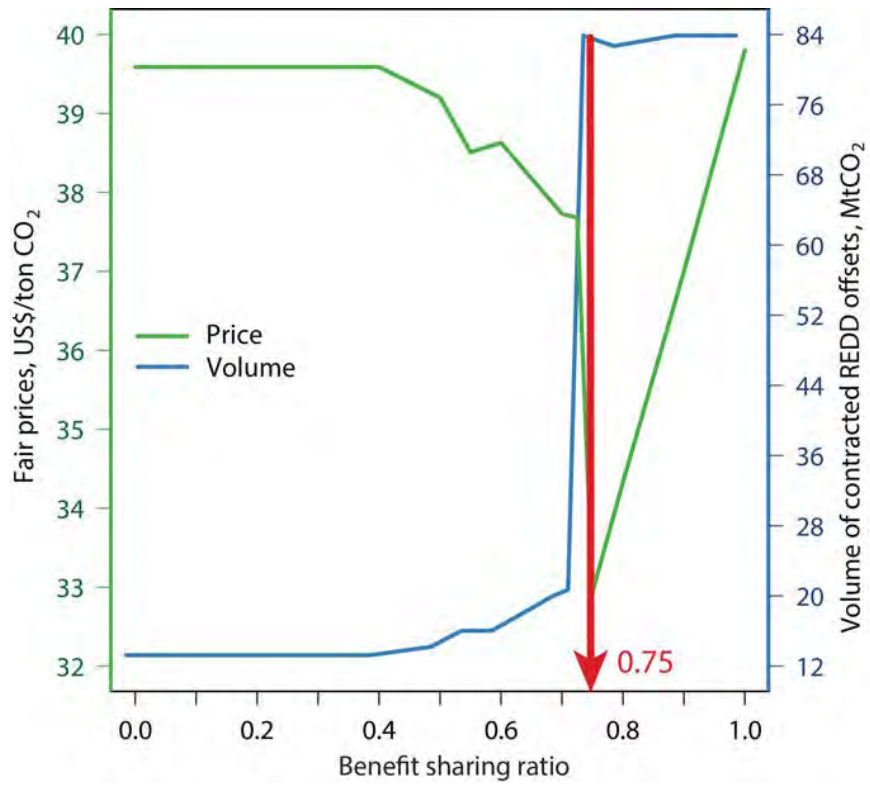
The UN REDD program aims to mitigate climate change through protecting forests in developing countries. Halting deforestation in this way means that the important carbon storage that forests provide is protected. Under REDD, a forest owner is given a certificate for each hectare of forest that they protect from logging (therefore avoiding CO_2 emissions). These can be sold to carbon emitters, such as energy producers, who can use them to offset their emissions.

At the moment, because the price for carbon emissions is very low, the best strategy for an electricity producer is to buy the bare minimum number of certificates. However, if they suspect that the price of carbon will increase, they may choose to buy more than they need, selling any excess at a profit in the future.

Researchers from the IIASA Ecosystems Services and Management Program investigated how to improve participation in the REDD certification program, by forest owners (sellers) and electricity producers (buyers) alike [1]. In particular they examined the impacts of a 'benefit-sharing mechanism.' Under such a scheme the forest owner would share in the profits that are made if the certificates are sold by the electricity producer at a profit. This reduces the forest owner's risk, since they do not lose out if the certificates are sold on at a much higher profit in the future.

The results showed that risk-averse attitudes could help get the scheme off the ground. This is because a cautious electricity producer would want to protect themselves against a rise in the price of carbon emissions by buying certificates. And a benefit sharing scheme could encourage a risk-averse forest owner to sell their certificates, since they will not lose out under a price hike for emissions.

To bring out these behaviors policymakers should give a clear indication that carbon prices will increase, and implement a benefit/risk sharing mechanism, the researchers conclude.



The impact of the benefit-sharing ratio on the contracted amount of REDD offsets. At every value of benefit-sharing ratio expected utilities of the forest owner and electricity producer stay the same, but the contracted amounts (blue line) and equilibrium prices (green line) differ.

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Ecosystem Services and Management Program

Collaborators

- Environmental Defense Fund, USA
- Mercator Research Institute on Global Commons and Climate Change, Germany
- London School of Economics, UK

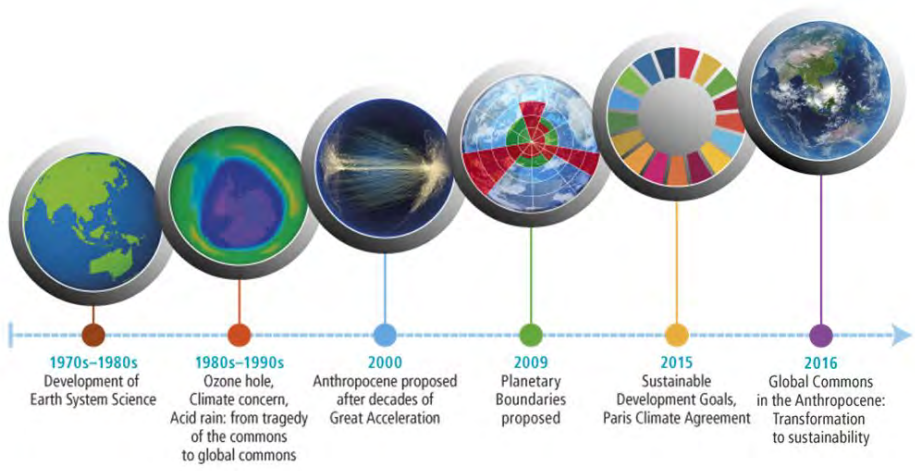
Further information

- Delivering Incentives to End Deforestation: NORAD DITED project
- The project "Options Market and Risk-Reduction Tools for REDD+" is funded by the Norwegian Agency for Development Cooperation under agreement number QZA-0464QZA-13/0074
- EU's Seventh Framework Programme grant agreement no. 603906 (ECONADAPT).

Humanity's shared resources

The global commons of the Anthropocene—ranging from rainforests to oceans and glaciers—are essential for the stability and resilience of our planet. Researchers from the Transitions to New Technologies Program and collaborators explored the changing nature of these global commons in the 21st century, in a paper published at the request of the Global Environment Facility (GEF) and the International Union for Conservation of Nature (IUCN).

'Global commons' are resources shared by all on Earth. They include natural resources such as the oceans and the atmosphere, along with human-made phenomena such as cyberspace. Traditional definitions rooted in international law state that to be 'global' the commons must lie outside national jurisdiction.



The Global Commons in the Anthropocene concept builds upon advances in research and in the international environmental and development policy process of the past decades.

But the stability and resilience of the planet are influenced not only by the resources shared among nations. All ecosystems, biomes, and processes that regulate the stability and resilience of the Earth system are common to humanity: they are the new 'global commons of the Anthropocene.' These are both global commons as recognized under international law but also resources within national jurisdictions, such as rainforests, sea ice, mangroves, and biodiversity [1].

In a 2016, researchers from the IIASA Transitions to new Technologies Program published a paper entitled "*Global Commons in the Anthropocene: World Development on a Stable and Resilient Planet*" exploring the changing nature of the global commons in the 21st century. The paper, written in collaboration with the Stockholm Resilience Centre, was requested by the GEF and the IUCN to complement their new initiative *Our Global Commons.*

The paper was launched at a science-policy conference International Dialogue on the Global Commons, convened at the US National Academy of Sciences jointly by GEF and IUCN. The conference kick-started a broader dialogue on the need to reassess the global commons at all scales in light of the growing human pressures on Earth's life-support systems and to renew efforts to develop a roadmap to manage the commons for the benefit of humanity.

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Transitions to New Technologies Program

Collaborators

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- Owen Gaffney, Stockholm Resilience Centre, Sweden

Further collaborators: GEF-Team under lead of GEF CEO and Chairperson Naoko Ishii, IUCN Team under the lead of IUCN Inger Andersen, Earth League Members


Riccardo Mayer | Shutterstock

Education matters for all Sustainable Development Goals

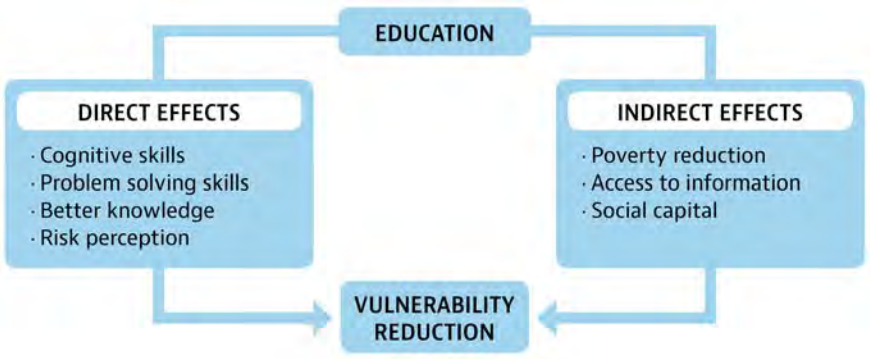
The Global Education Monitoring Report 2016 established that education is at the heart of sustainable development. IIASA made a considerable contribution to the report, which, according to IIASA Distinguished Visiting Fellow Jeffrey Sachs: "should set off the alarm bells around the world and lead to a historic scale-up of actions to achieve Sustainable Development Goal four: education for all."

The Global Education Monitoring (GEM) report is an editorially independent, evidence-based annual report published by UN Educational, Scientific and Cultural Organization, which provides an authoritative global review of education. Its mandate is to monitor progress towards the education targets in the new Sustainable Development Goals (SDGs) framework. The GEM report draws on the latest available data and evidence, and includes extensive research from leading experts around the world.

In 2016, scientists from the IIASA World Population Program were invited to make a contribution on the topic "Education and the SDGs: Long-Term Interactions." This involved producing a comprehensive literature review of the current evidence on education's impact on other key sectors of development, such as inclusive economic growth; inclusive social development; environmental sustainability; governance; and peaceful, just, inclusive societies. This review examined interlinkages between the different SDGs, in particular looking at how progress towards achieving the education goal four will help to achieve the other 16 goals. The researchers also modeled different future scenarios for projecting patterns of education expansion if the SDG targets are met [1].

Examining the issue from four angles—people, planet, prosperity, peace— the analysis shows there are numerous synergies between education and the other SDGs. In terms of "people" the effect of education on social development, including health, is well known. The chapter on "planet" focuses on the role of education (both in terms of formal schooling and interventional education) in reducing vulnerability to climate change and promoting sustainable lifestyles through both direct and indirect mechanisms.

A large number of studies demonstrate how formal education reduces vulnerability in the face of natural disasters, building resilience and adaptive capacity. When it comes to sustainable lifestyles, the relationship is quite complex: while the highly educated are more likely to be concerned about the impacts of their behaviors on CO_2 emissions and the environment in general, their associated higher income levels tend to mean higher consumption levels and higher emissions.



The processes through which education contributes to vulnerability reduction

A review of over 50 studies reveals mixed evidence, though the finding that the more highly educated are more willing and more able to adopt new technologies suggests that formal education may be key to ensuring environmental sustainability in the long term.

The chapter on "prosperity" explores the concept of inclusive economic growth in relation to education. Inclusive growth is spread across all sectors, creating productive employment opportunities for the majority of the labor force, including traditionally marginalized groups. The review of the literature reveals that education can promote broad-based, fast, sustainable economic growth by contributing to the movement of labor from less productive agriculture to more productive manufacturing and services, and by making workers more productive.

The quantitative scenarios of educational expansion underlying the population projections presented in the report are the result of refinement of the education model presented in [2]. The projections showed the share of the population reaching or exceeding a given attainment level in different countries and between genders.

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World Population Program

Collaborators

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- Vienna University of Economics and Business (WU), Austria

Protecting fisheries from evolutionary change

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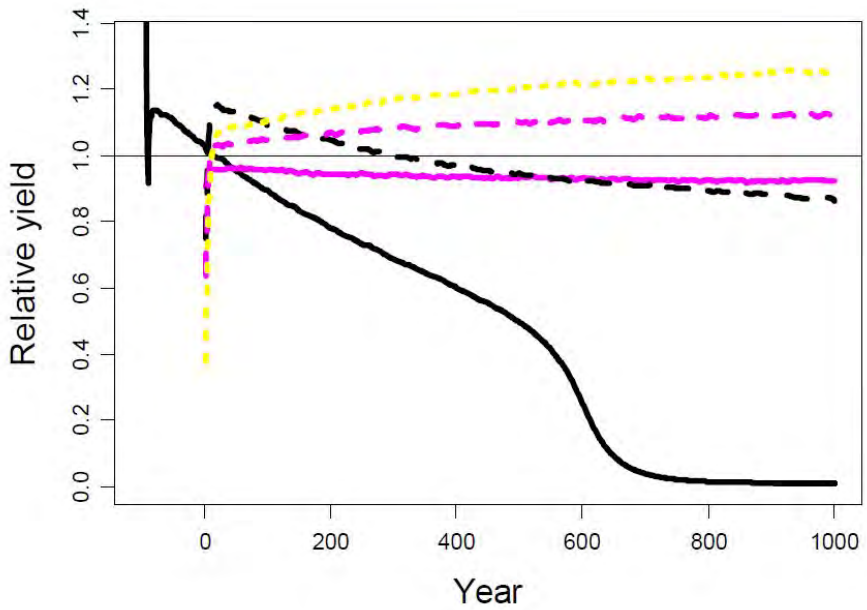
Evolutionary changes could lead to reduced fishery yields. In 2016 researchers from the IIASA Evolution and Ecology Program showed how alternative management practices could mitigate the problem in a key North Sea fishery.

North Sea plaice is the most commonly fished flatfish in Europe, with landings of around 120,000 metric tons per year. But if current trends continue, evolutionary changes will lead to a decreased catch of this important food source.

Previous research has shown that fishing can cause evolutionary changes in fish populations, with impacts such as earlier maturation or smaller size. This is because removing the largest fish from a population also removes them from the gene pool. Over a few generations, this can lead to smaller fish that mature at an earlier age, which translates into a smaller catch for fishers.

These impacts have already been observed in the plaice fishery. In addition to reducing the amount of fish available for catch, researchers surmise that such changes will be difficult or slow to revert and can make fish populations more vulnerable to collapse.



Fishing North Sea plaice causes it to evolve, changing how the fishery's yield develops.
Black continuous line: The current fishing practice causes long-term yield erosion.
Black dashed line: Reducing the fishing pressure on all fish to one half still causes long-term yield erosion, albeit at a slower pace.
Magenta continuous line: Reducing the fishing pressure on large fish to one half stops the yield erosion.
Magenta dashed line: Reducing the fishing pressure on medium-sized fish to one half and on large fish to one quarter causes a long-term increase in yield.
Yellow dotted line: The best yield increase is achieved by protecting small fish combined with reducing the fishing pressure on medium-sized fish to one quarter and on large fish to one eighth.

This study is the first to combine the quantification of evolutionary impacts for a specific stock with tailored projections for different management scenarios. To conduct the study, the team applied models using the Evolutionary Impact Assessment framework, developed by IIASA researchers and their colleagues to provide fisheries managers with a set of tools to understand the potential impacts of evolutionary change on fisheries.

Underscoring cautionary findings reported in earlier IIASA studies, for example on Northeast Arctic cod fished north of Norway and on northern cod caught east of Canada, the new research draws attention to the accumulating 'Darwinian debt' current fishing practices are incurring. In other words, each year these practices go on is likely to require many more years of different fishing practices before the exploited stocks recover from the evolutionary changes.

Management practices that target fish differently from current practices could help mitigate the problem and maintain a higher sustainable catch, the study shows. By shifting fishing pressures from the largest fish to intermediately sized fish, fisheries managers could ensure that the population stays stable from an evolutionary perspective.

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Evolution and Ecology Program

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- Aquaculture and Fisheries Group, Wageningen University, Netherlands

Energy and the Sustainable Development Goals

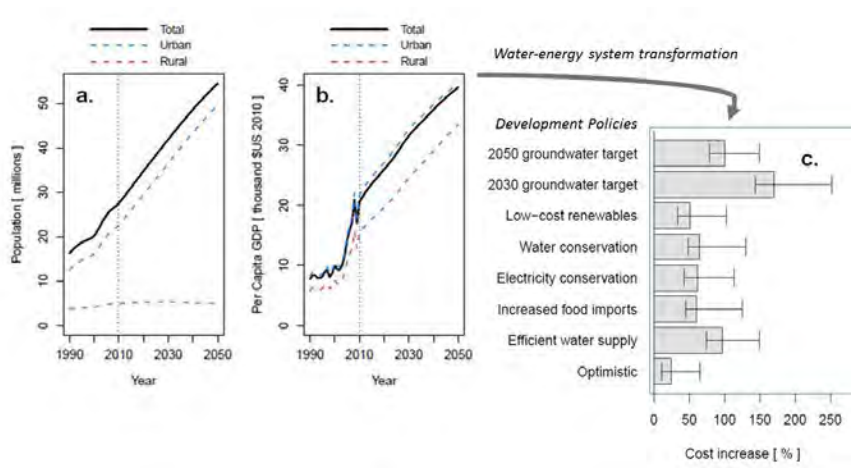
In exploring the complex interplay between climate action and sustainable development, the IIASA Energy Program (ENE) has assessed what makes climate policies effective. Specifically the researchers have explored the interaction of climate policy with a host of other policy objectives, including the implications for water and energy security.

Designing effective policy is crucial if we are to avoid catastrophic climate change. To determine what works, researchers from the *Linking Climate and Development – Leveraging International Networks and Knowledge Sharing* (CD-LINKS) project examined 19 case studies. Barriers to policy success included a lack of money and required infrastructure, or contractual challenges when many parties needed to establish business relations. When it came to the interaction of climate and sustainable development, many cases—especially those in developing countries—showed that other aspects of sustainability, such as reducing air pollution, were the drivers behind policies and climate mitigation was essentially a co-benefit.

Through collaboration with international modeling teams (in Brazil, China, the EU, India, Japan, Russia, and the USA) the CD-LINKS project has also developed transformation pathways that coincide with national contexts but at the same time are consistent with the Paris Agreement objectives of limiting temperature change to 1.5-2°C.

Limiting temperature change in this way will require a transformation of the global energy system. However, different climate-friendly energy technologies require varying amounts of water, and therefore such a transition could have a substantial impact on water demand. To examine these impacts, ENE enhanced the Model for Energy Supply Strategy Alternatives and their General Environmental Impact (MESSAGE) to account for energy-related water use. After applying the model to a range of scenarios, all of which would ensure a 2°C limit [1], the researchers demonstrated that strategies combining improved energy efficiency with a rapid scale-up of solar and wind power generation can yield climate stabilization, reduced water demand, and improved water quality.

A case study on the Kingdom of Saudi Arabia illustrated the critical need of balancing water use and climate objectives on the national level. In Saudi Arabia, a transition away from groundwater use by the year 2050 could increase national electricity demands by more than 40% relative to 2010 conditions. Simon Parkinson and colleagues conclude that the increase in energy demand would be primarily due to the expansion of energy-intensive desalination and water conveyance [2][3].

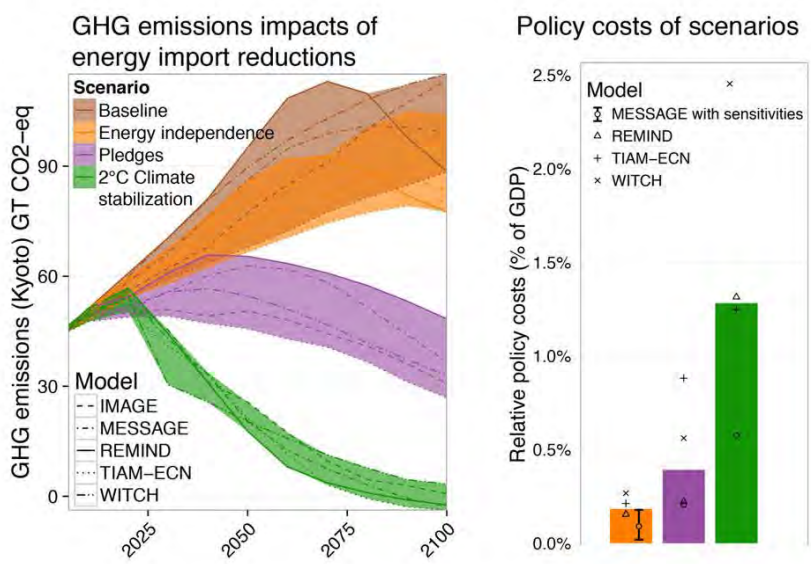


Economic impacts of combined climate and groundwater policies in Saudi Arabia. a. Population to 2050; b. Income to 2050; c. Cost for combined water-energy system development relative to a case no groundwater or climate targets [2].

Another study examined the impact of energy imports on greenhouse gas emissions. While it has been established that energy imports would fall if greenhouse gas emissions were reduced, the team wanted to know if emissions fall when energy imports are restricted.

The results showed that while emissions reductions generally benefit energy security—by reducing energy imports—policies focusing on energy security do not show the same co-benefits for climate targets. In fact, policies to reduce energy imports would only lower emissions enough to limit warming to roughly 3.5°C to 4°C.

The study also compared the relative costs of energy independence and climate policies. Reducing energy imports would cost between 3 and 20 times less than stabilizing climate change at 2°C by 2100, but would be comparable to the cost of the climate pledges. Thus, while climate policies can lead to lower energy imports, these can be reduced more cheaply through energy import restrictions.



The impacts of energy import restrictions on greenhouse gas emissions and the relative costs of energy independence and climate policies.

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Energy Program

Collaborators

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- Potsdam Institute for Climate Impact Research, Germany
- Energy research Centre of the Netherlands
- PBL Netherlands Environmental Assessment Agency
- University of Utrecht, Netherlands
- Central European University
- Euro-Mediterranean Center on Climate Change, Italy
- Institute of Communications and Computer Systems, Greece
- Institute for Sustainable Development and International Relations, France
- The Energy and Resources Institute, India
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- Wageningen University, Netherlands
- University of East Anglia, UK
- Energy Research Institute of the National Development and Reform Commission, China
- Tsinghua University, China
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- Higher School of Economics, National Research University, Russia
- National Institute for Environmental Studies, Japan
- Research Institute of Innovative Technology for the Earth, Japan
- Pacific Northwest National Laboratory, USA
- Korea Advanced Institute of Science and Technology, Republic of Korea
- European Commission Joint Research Centre

Health, wellbeing, and aging in the Arctic

Arctic communities may have significantly different aging patterns to those in the southern areas of the same country, IIASA research has shown. Using new measures of aging they showed that national policies should be adjusted to take into account these differences. In a second study, the Arctic Futures Initiative looked into variation in wellbeing across the Barents region, emphasizing the importance of education to facing socioeconomic challenges and adapting to climate change in these northern countries.

Population aging has the power to transform small communities in the Arctic, and policies on important social factors, such as care for the elderly, must be designed with this in mind. In a 2016 study, IIASA researchers applied new measures of aging developed at IIASA. Known as "prospective age," these measures look at the number of years a person has left to live, so a healthy person of 60 years old may have the same prospective age as someone in bad shape at 45. They found that population aging in remote Arctic territories is different, sometimes significantly, from the ''mainland'' (e.g., Greenland versus Denmark or Nunavut versus Canada). Policies related to aging should be adjusted to the specifics of the Arctic, the researchers conclude, rather than following nationwide patterns [1].

In another study, a member of the Arctic Futures team examined wellbeing in the Barents region, incorporating population, health, education, and environmental factors. In parcticular, they analyzed recent demographic trends across gender and ethnicity, including depopulation, aging, mortality, and fertility. They also investigated the impacts of air and water contamination, food insecurity, housing conditions, and new climate-change driven diseases on the health and living conditions of the Barents people.

The results showed that these factors varied significantly across the Barents region and this variation has been increasing in recent decades, despite efforts to harmonize development in the region [2]. The study also highlighted the importance of education in tackling socioeconomic challenges as well as adapting to climate and other sweeping changes occurring in the Barents region.

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Arctic Futures Initiative

Science into policy

Facing the complex challenges of global change requires robust policy with a strong scientific basis; to achieve this, IIASA works closely with policymakers around the world.

Selected highlights

Shaping European bioenergy policy

Robust land-use management

New ways to measure age and aging

Building security for farmers in Ethiopia

Energy and landscape sustainability in Indonesia

Guiding science and policy to robust climate action

Counteracting disease spread over city commuter networks

Informing European air quality policies

Can insurance effectively support climate resilience?

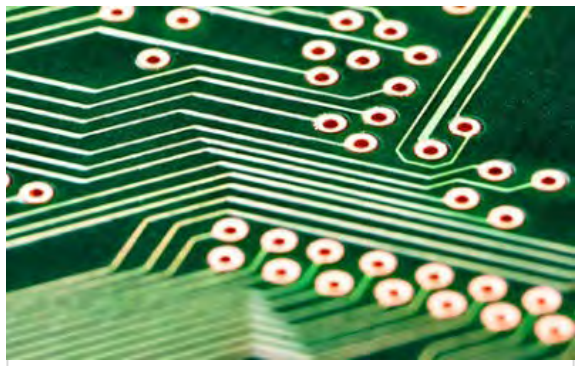
Water security in Asia

Exploring the new phenomenon of economic platforms

Achieving sustainable agriculture

Rethinking expert engagement in participatory processes

Loss and damage in the Arctic under climate change



How to make fast transitions to sustainable pathways

Economic cooperation between the EU and Eurasian Economic Union

Russian Demographic Data Sheet

Labor market and migration across Eurasia

Shaping European bioenergy policy

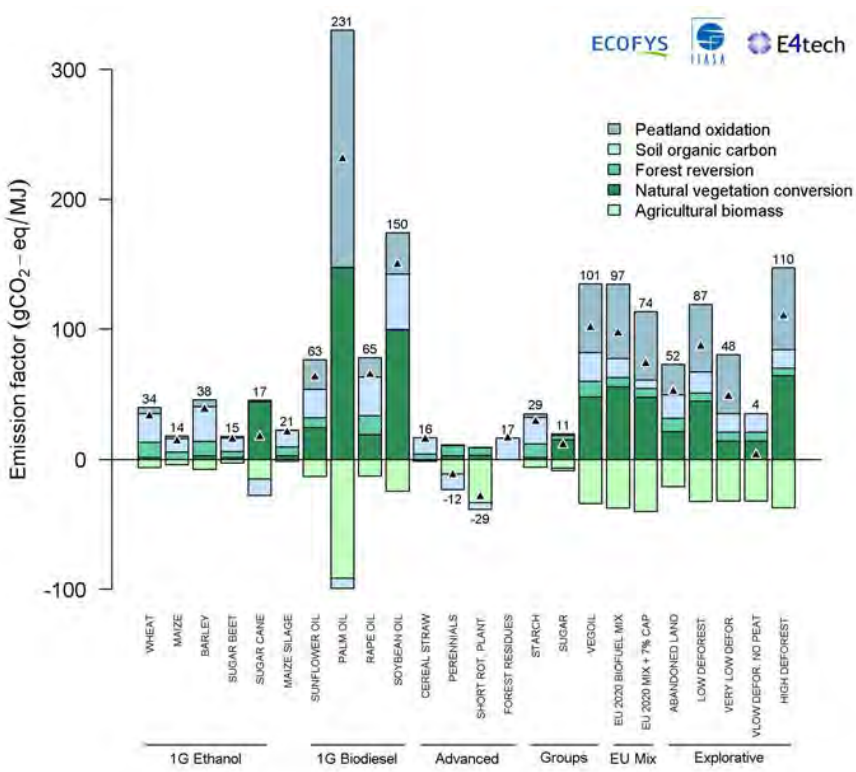
Bioenergy was once hailed as a key part of tackling climate change but there have been rising concerns over how efficiently it can reduce greenhouse gases emissions and the amount of land it requires. The IIASA Ecosystems Services and Management Program has been analyzing these issues for the European Commission, helping to shape EU policies.

In the EU, the use of bioenergy is on the rise. This is partly due to an increased focus on renewable energy, intended to reduce greenhouse gas emissions and increase energy security. However, biofuel production can occupy land that would otherwise be used to grow food and feed. This displacement can lead to deforestation when other areas are converted to agriculture, threatening biodiversity and offsetting some of the climate benefits.

In a study for the European Commission, IIASA researchers assessed the impacts of different biofuels on land-use change and climate. On one end of the spectrum, the study showed that certain types of vegetable oils, such as palm or soybean oil, can lead to significant greenhouse gas emissions. And on the other end, second generation biofuels— produced from waste such as forestry residues left after logging or cereal straw—showed a good performance overall, with several cases of net negative emissions.

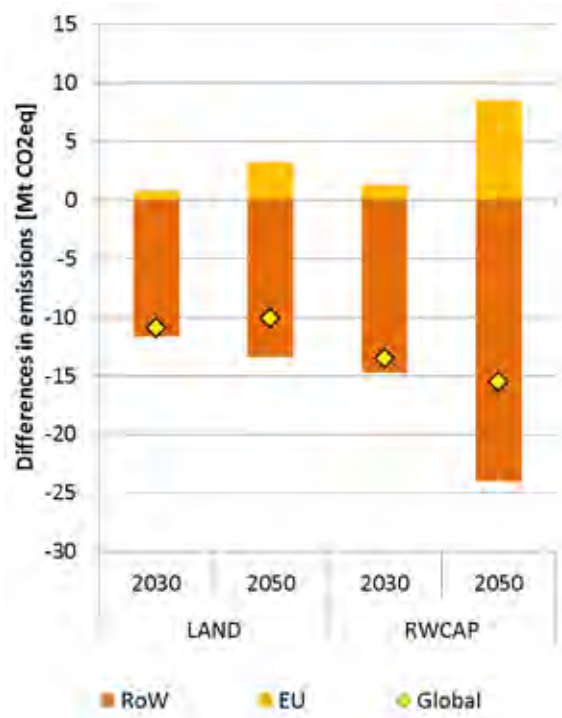
The study was used as important input to the 2016 proposed revision of the EU Renewable Energy Directive. Under the new proposal, starting in 2020, the European Commission intends to promote advanced biofuels that do not compete with food, and to progressively phase out crop-based biofuels from the EU energy consumption.

In other work on biofuels, the European Commission asked a group of researchers led by IIASA to assess how increasing bioenergy demand would affect forests, the forestry industry, and other sectors that rely on biomass.



Emission intensity of different biofuel feedstock consumed in the EU and analysis of impact of some policy mixes

The team showed that increased demand would place increased pressure on forest ecosystems and their resources, both in and outside of Europe. However, worldwide protection for biodiversity and land with high carbon storage could lead to global greenhouse gas emissions from the land-use sector 10 metric megatons lower than without protections.



Differences in global land-use net emissions for the Land and Roundwood Cap scenarios in comparison to a reference scenario. The Land scenario represents a case where land criteria are implemented to restrict biomass harvests in areas with high biodiversity value and/or high carbon stocks, and the Roundwood Cap scenario represents a case with the same land criteria as well as a cap on the use of roundwood for energy.

Using these IIASA analyses, the European Commission proposed a number of revisions to the Renewable Energy Directive to ensure that bioenergy achieves robust and verifiable emissions savings.

Further work for the European Commission concerned the importance of the EU's land-use sector as a carbon sink. Following the Paris climate agreement, the European Commission published a proposal to include the land-use sector in its emission-reduction commitments. The commitments, as well as their breakdown to individual countries—known as the "Effort sharing Regulation"—were based on research and modeling work conducted at IIASA using the Global Biosphere Management and Global Forest Models.

Based on IIASA analyses, the European Commission proposed to allow member states to use up to 280 metric megatons of CO_2 of land-use sector credits—from afforestation or grassland management—from 2021-2030 to achieve their mitigation targets. This should provide additional incentives for mitigation in the land-use sector.

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Ecosystem Services and Management Program

Collaborators

- Air Quality and Greenhouse Gases Program, IIASA
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- EuroCare, Germany
- Indufor Oy, Finland
- Institute for European Environmental Policy, UK
- Öko-Institut e.V., Germany
- European Forest Institute, Finland
- European Commission
- Ecofys, Netherlands
- E4tech, UK

Further information

- Impact Assessment LULUCF
- Proposal for an Effort Sharing Regulation 2021-2030
- Impact assessment of the revised renewable energy Directive
- EU biofuels study

Robust land-use management

Providing policymakers with robust guidance on land-use management is becoming increasingly difficult under the uncertainties of climate change. IIASA researchers have now updated the institute's large-scale land-use model to better incorporate these uncertainties, and used it to provide the Ukrainian government recommendations for sustainable management of agriculture.

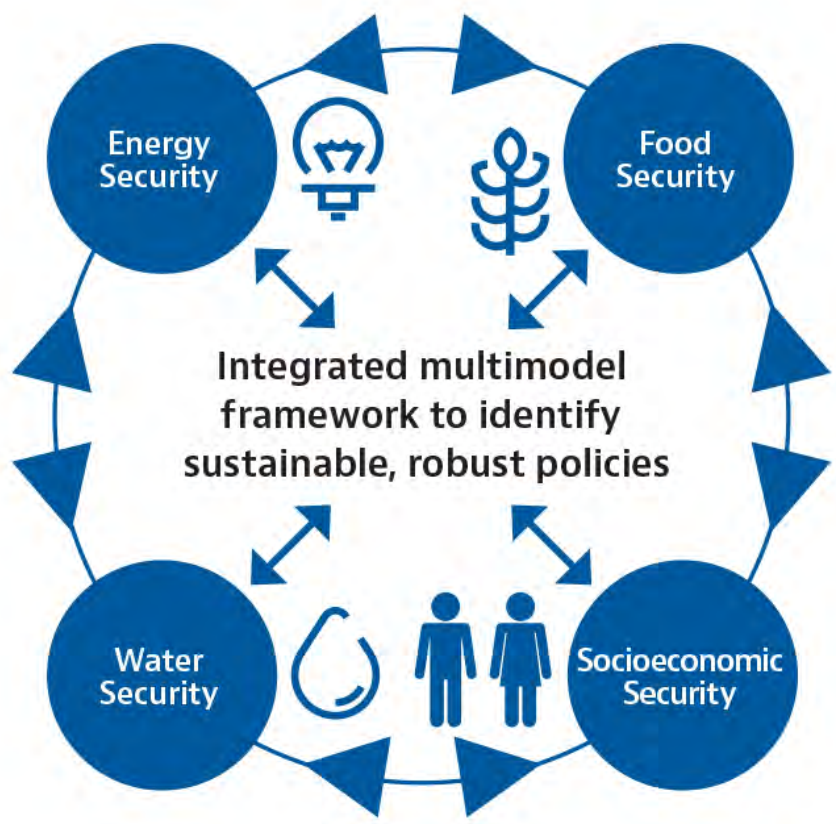
The IIASA Global Biosphere Management Model (GLOBIOM) is used to analyze the competition for land between agriculture, forestry, and bioenergy. While it was originally developed as a global model, GLOBIOM can be adjusted to analyze strategies for sustainable development on national scales as well.

Agriculture currently generates about 10% of Ukrainian GDP and national food security largely relies on small, often family-owned farms, which meet domestic demand for major crops despite the fact that they are neither efficient nor profitable. At the same time, large agri-businesses produce more profitable crops and take advantage of the economy of scale, exporting most of their produced food abroad.

To help policymakers tackle these and other problems, researchers from the Advanced Systems Analysis Program in collaboration with the Ecosystems Services and Management program, working as part of the project *Integrated Modeling of Robust Solutions for Food, Energy, and Water Security Management*, have down-scaled GLOBIOM to apply it to Ukraine [1]. This can provide detailed, national-level advice that is consistent with global targets, and IIASA work has now been used as input for Ukraine's Strategy of Agriculture and Rural Development, prepared with the support of the UN Food and Agriculture Organization.

Recommendations for policymakers must be robust in the face of uncertainties: a policy that only works in an entirely predictable world is useless.

To ensure that GLOBIOM provides guidance that is robust under all eventualities, IIASA researchers developed a stochastic version of the model that incorporates uncertainties and risks related to weather variability and climate change. The team has also improved the way GLOBIOM models the vulnerability of global supply chains to shocks such as natural disasters or price spikes, by including risks of low-probability, high-impact events. Their analysis showed clear benefits of the stochastic technique over the commonly used deterministic approach [2].



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Advanced Systems Analysis Program

Collaborators

- National Academy of Sciences, Ukraine

Further information

IIASA impact sheet: Robust food, energy, water, and land management

New ways to measure age and aging

Defining aging by physical and mental health rather than chronological age makes global population aging look less rapid, research from the IIASA World Population Program shows. It is important to have these characteristic-based measures of age in addition to conventional chronological age, not only because behavior is influenced by expected remaining life expectancy, but because important economic and social aspects depend on it as well.

Most studies of population aging focus on only one characteristic of people: their chronological age. Many other important characteristics, such as physical and mental health, do vary with age, but they also vary over time and from place to place. IIASA research has supplemented traditional measures of aging with new ones that consider characteristics including remaining life expectancy, health, or hand-grip strength.

Many social and economic factors are influenced by these kinds of characteristics. For instance, retired people are already more likely to take courses to help them enjoy new leisure-time activities because they expect to live longer. The number of requests for the provision of certain medical procedures also depends on the number of remaining years of life.

These findings also have consequences for policy. For example, medical expenditures are especially high in the last years of life. In forecasting these expenditures, it is important to take into consideration that, with increasing life expectancies those last years of life happen at an ever older age. Forecasting medical expenditures only on the basis of chronological age produces figures that are too high and could lead to erroneous policy decisions.

Pension policy can also be informed by this research. A simple alternative public pension system can also be developed using the concept of α-ages. These correspond to different characteristics of the population and allow us to specify a pension system where the fraction of adult years spent eligible for a pension remains constant. Such a system is equitable in the sense that the ratio of the number of years of pension to the number of years of working remains fixed, even as life expectancy changes. This may help in assessing policies concerning the age at the entitlement to a full public pension.

One of the most commonly used measures of population aging is the change in the "old-age dependency ratio." This ratio relates the number of "old-age dependents," who are traditionally assumed to be everyone 65+ years old, to those assumed to support them, people from 20–64. However, rather than assuming everyone over 65 is dependent IIASA researchers use people's characteristics to define old age, such as a remaining life expectancy of 15 years or less. Figures 1 and 2 show the difference in population aging statistics when using a traditional approach and a prospective, characteristics-based approach. These figures illustrate that predictions for population aging are not nearly as extreme if a characteristics approach is used.

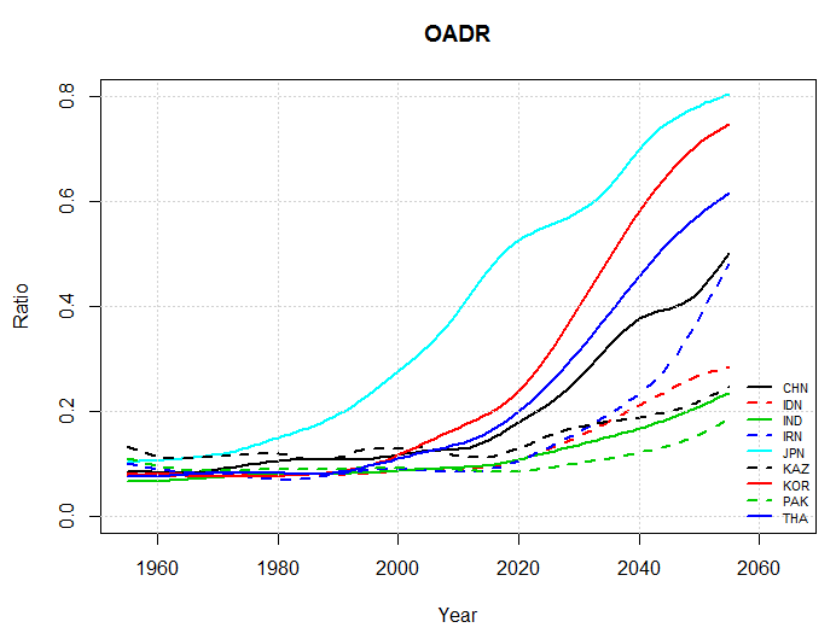

Figure 1. Traditional old-age dependency ratio (OADR) (selected Asian countries), 1955-2055.

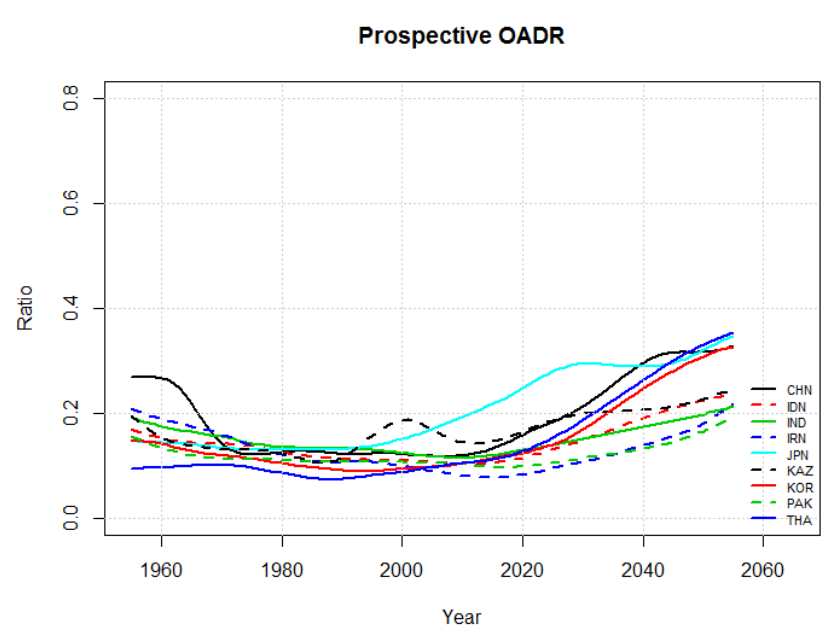

Figure 2: Prospective old-age dependency ratio, based on a remaining life expectancy of 15 years or less (selected Asian countries), 1955-2055.

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World Population Program

Further information

Funding: ERC-funded Reassessing Aging from a Population Perspective (Re-Aging) project (under Grant ERC2012-AdG 323947-Re-Ageing).

Building security for farmers in Ethiopia

AGsPhotography | Shutterstock

Smallholder farmers in Ethiopia are especially vulnerable to the threats of climate change, but by expanding irrigation, providing subsidies for fertilizers, and investing in infrastructure, policymakers can improve smallholders' income and food security, IIASA research has shown. The work also provided input to the Global Biosphere Management Model, leading to insights into the effects of different policy measures regarding food security and poverty.

In Ethiopia, 84% of the population lives in rural areas, where they produce 90% of the country's grain with, on average, less than one hectare of land per person. A rapidly increasing population, along with climate-related disasters like droughts, and competition for land, water, and energy, are threatening livelihoods and food security in the country.

In a study funded by the International Fund for Agricultural Development (IFAD), IIASA researchers from the Ecosystems Services and Management Program set out to map the distribution of different types of smallholder farms in terms of poverty and food security. The team developed a new methodology based on: agro-ecological zone (i.e., biophysical environment and climate), farm size, main activities, and intensity of production.

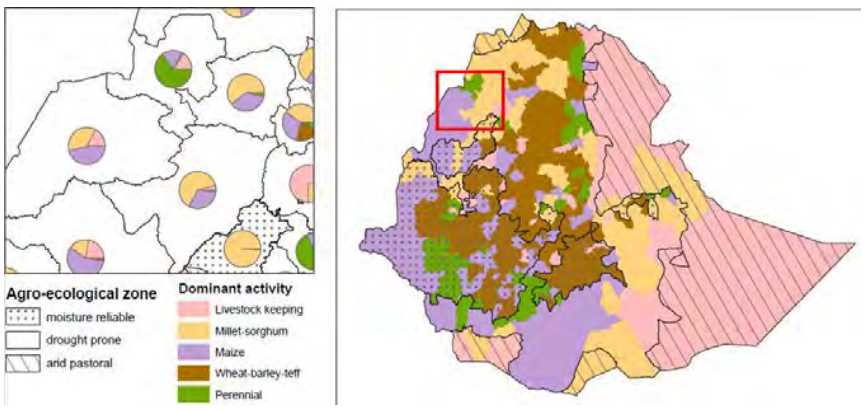
The researchers analyzed the effects of three policy interventions on poverty and food security:

1. the development of infrastructure networks to improve access to markets;
2. the development of irrigation infrastructures to increase production;
3. fertilizer subsidies to increase production.

Overall, a combination of irrigation expansion with infrastructure development and fertilizer subsidy would be most beneficial for smallholder income and overall food security, the researchers found. The results showed that livestock-oriented systems are less profitable than crop-oriented systems and more prone to food-insecurity.

This work, valuable in itself, also served as input to the IIASA Global Biosphere Management Model. This country-specific, household-level data improved the model in terms of both its production and consumption analyses. For Ethiopia, it meant that farming systems could be modeled in such a way that allows for transitions from one type of farming system to another, important for assessing the policy options of the future.

The results were used to provide support to Ethiopian policymakers, as well as helping to define the most suitable locations for irrigation schemes in the second phase of an IFAD project, the *Participatory Small-Scale Irrigation Program*.



Dominant combinations of activities and agro-ecological zone by district (known as woreda in Ethiopia) (right) and the distribution of farming systems for the subset in the red rectangle (left).

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Ecosystem Services and Management Program

Collaborators

- Research and Impact Assessment Division, International Fund for Agricultural Development, Italy


Rattanamanee Patpong | Shutterstock

Energy and landscape sustainability in Indonesia

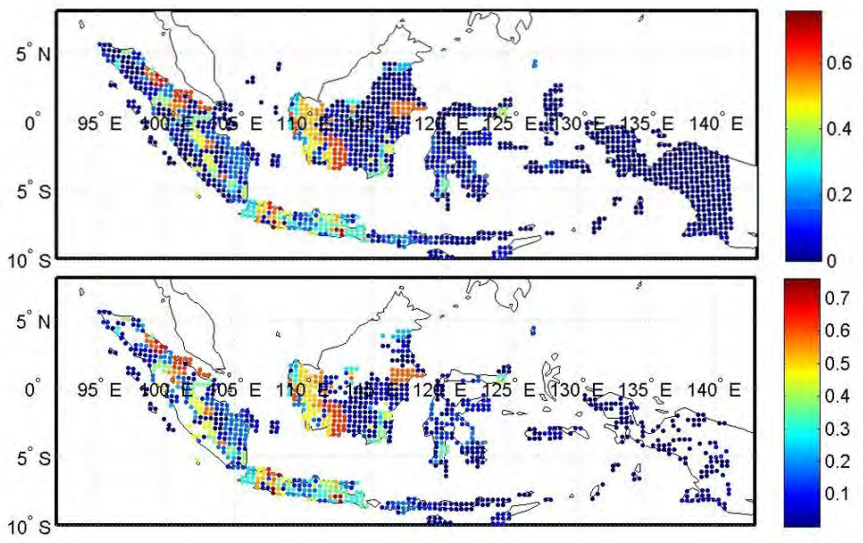
To support the government of Indonesia to plan a sustainable energy system, researchers and collaborators from the IIASA Tropical Futures Initiative developed a special version of the institute's BeWhere model. This will develop and assess an alternative energy network for the country, taking into account protection for its natural and cultural heritage.

As climate change progresses, the urgent need for an effective network of renewable energy producers grows. The IIASA BeWhere model tracks the costs and greenhouse gas emissions across every section of such a network. By testing different policy options at every step of the supply chain, the model identifies all possibilities for increasing efficiency and reducing costs and emissions. This provides valuable information on which technologies should be used; the resources needed to create the energy; the best locations for renewables; and the most efficient way to distribute energy to the consumers.

In 2016, researchers from the Tropical Futures Initiative adapted the model for Indonesia, considering renewable energy technologies—such as solar and geothermal—alongside existing coal plants, which could be adapted to burn a mix of coal and biomass.

Using the model, the team will identify an optimally adapted renewable energy mix for the country. To ensure holistic sustainability, the researchers will include nature protection and cultural heritage areas, where biomass harvesting and power plant sites will likely be limited—depending on the protection type and renewable energy technology.

For Indonesia to achieve its goal of having renewable energy make up a 23% share of the national energy mix by 2025, biomass for bioenergy is required from across the country, the model results show (top graph). When the model takes into account conservation areas, the picture is different, allowing decision makers to examine all aspects of sustainability policy (bottom picture).



Biomass use intensity for bioenergy production for 23% renewable energy contribution to the Indonesian energy mix considering all forest wood possibly available (top graph) and omitting the primitive forest (bottom graph).

This work is part of an online decision-support platform focusing on renewable energy development in Indonesia. The portal aims to be a one-stop shop for data on renewable energy resource availability, as well as providing user-friendly analysis tools that policymakers can use to make sound decisions.

References

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Tropical Futures Initiative

Collaborators

- World Resources Institute Indonesia
- Ministry of Energy and Mineral Resources of Indonesia

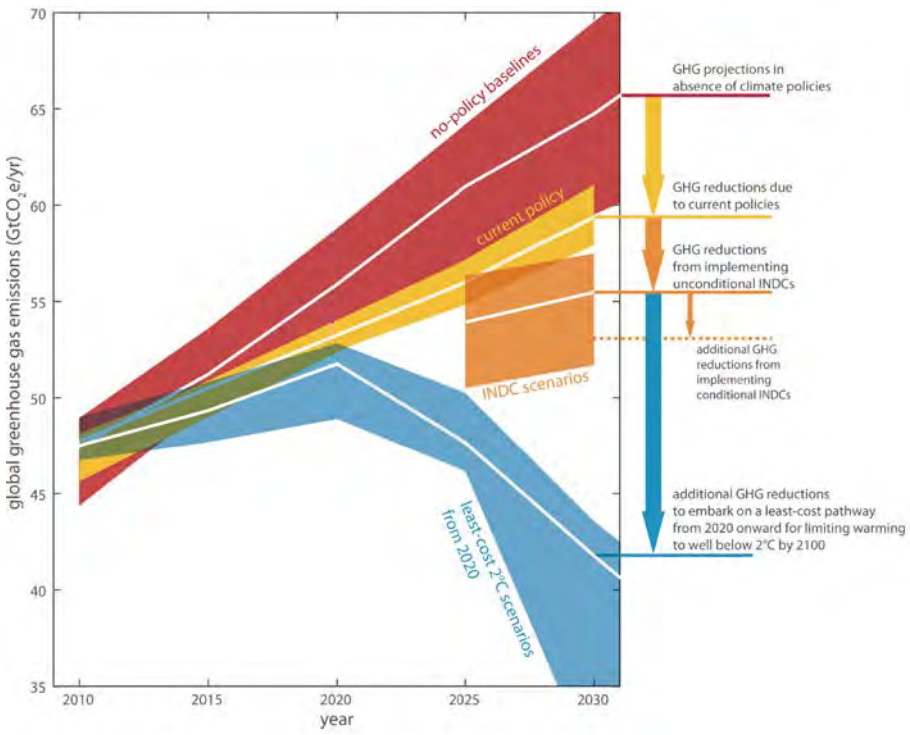
Guiding science and policy to robust climate action

International climate policy requires scientific evidence to steer it towards robust outcomes. In 2016, the IIASA Energy Program (ENE) worked to provide this by assessing what it will take to meet goals of the Paris climate agreement, whether national climate pledges live up to those ambitions, and how to ensure that future research yields policy-relevant results

The Paris Agreement set a target of limiting warming to well below 2°C and further pursuing efforts to limit it to 1.5°C. To understand where we are starting from, ENE researchers carried out a meta-analysis of the current emissions reduction pledges and whether they can achieve the Paris Agreement's goals [1].

The current pledges fall significantly short of putting the world on track to the goals, the results show (see figure). The work also highlighted the fact that the relatively weak pledges in the current agreement may result in a greater reliance on controversial technologies such as bio-energy combined with carbon capture and storage to make up the shortfall in the near term.

Along with the absolute emissions' savings, the equity of the current pledges is also a key issue. In a further study, IIASA researchers revealed that not only are current pledges not sufficient, they do not spread efforts fairly amongst countries [2].



Assessment of current Paris Agreement emissions reduction pledges. Current pledges (orange) fall far short of pathways that can limit warming to below 2°C with at least a two-out-of-three chance (blue range). Adapted from [1].

To create truly effective climate policy it is important that policymakers are aware of the non-negotiable limits that they must abide by to prevent dangerous rises in temperature. To shed light on these "geophysical limits" IIASA researchers examined a case where there was a greater than two-out-of-three chance that warming was limited to below 2°C. To achieve this, global CO_2 emissions from 2016 onwards should not exceed 590–1,240 billion tons of CO_2, the researchers found [3].

Oil resources and their markets play an essential part in climate change mitigation. In a 2016 study, ENE researchers demonstrated that sustained high or low oil prices could have a substantial impact on CO_2 emissions. In fact, the two price extremes could result in an increase or decrease in emissions of 55-194 gigatons of CO_2 by 2050 —amounting to 5-20% of the cumulative emissions allowable for keeping temperature change under the 2°C threshold.

When oil prices are high, there is an effect on demand, as consumers increase efficiency to save money. However, the emissions savings are not larger than one would expect because at high oil prices other carbon-intensive fuels, such as coal, are more likely to be used—either for electricity or liquid fuel production. The team found that the emissions impact depends not just on future oil prices, but other uncertainties such as whether oil and gas prices decouple going forward; the future potential of sustainable bioenergy supplies; and the costs and availability of electric vehicles.

If the goal is to mitigate carbon substantially, the researchers conclude, high oil prices offer no substitute for climate policies [4].

Finally, in the afterglow of the Paris Agreement, many important, policy-relevant questions arose. However, these questions were often unclear to scientists without a strong understanding of policy. Capitalizing on its expertise at the science-policy interface, ENE published two perspective articles that will help catalyze policy-relevant research. One piece directly addressed the geoscience research community [5], while a second targeted the broader global environmental change community, with a focus on the Paris Agreement's temperature goal [6].

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Energy Program

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- Potsdam Institute for Climate Impact Research, Germany
- PBL Netherlands Environmental Assessment Agency, Netherlands
- NewClimate Institute, Cologne, Germany
- Wageningen University and Research Centre, Wageningen, The Netherlands
- World Resources Institute, Washington DC, USA
- University of Cape Town, Cape Town, South Africa
- Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil National
- Center for Climate Change Strategy and International Cooperation, Beijing, China
- Graz University of Technology, Graz, Austria
- University of Exeter, Exeter, UK
- Canadian Centre for Climate Modelling and Analysis, Environment Canada, Victoria, Canada
- University of Oxford, Oxford, UK
- Marianne Fay and Morgan Bazilian (World Bank)

Counteracting disease spread over city commuter networks

To fight the outbreak and spread of disease across public transport networks, city health officials should target the largest station, as preventative measures there are likely to be substantially more effective than at any of the smaller stations, IIASA work has shown. For the study researchers developed a new method for identifying the stations with the highest benefits in fighting disease spread, and tested it on the Tokyo public transport system.

Public transport networks in large cities are the perfect way for a disease to spread. The confined spaces, the high numbers of people passing through—especially during the daily commute—mean that a virulent disease could make its way across the city in even a few hours.

To face this challenge, health officials need to design countermeasures that fight disease spread while remaining cost effective. A promising strategy, research shows, is to target the hubs of the transport network, such as particularly busy stations. A study by the IIASA Evolution and Ecology Program uses innovative network analysis to show how such hubs can best be identified.

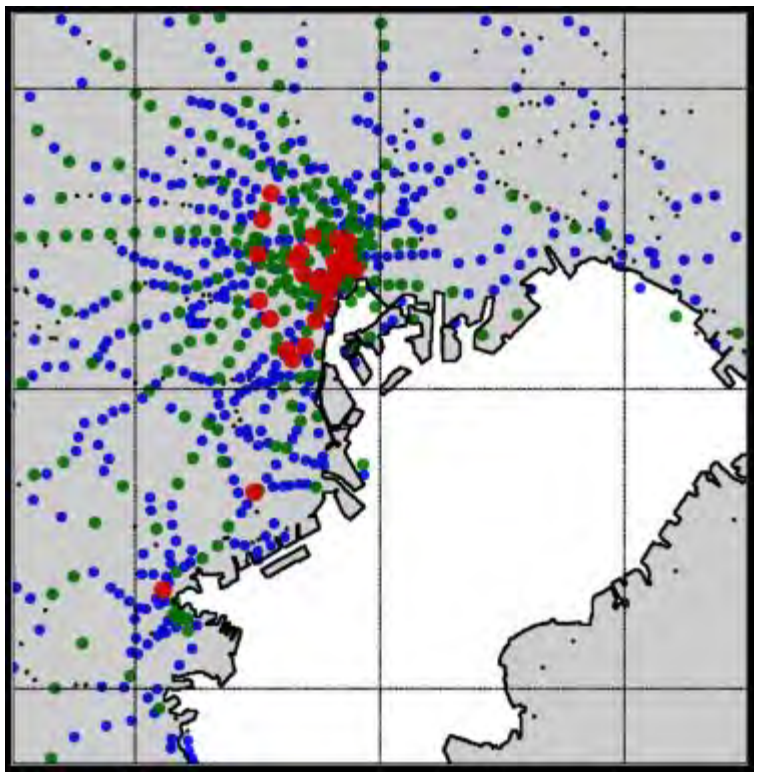
Using Tokyo as a test case, the team developed a new type of "network centrality measure," which quantifies the relative importance—in terms of disease spread—of each location in the network.

The results show that the impact of taking countermeasures at the largest station is more than 1,000 times more effective in stopping disease spread than at the second largest station, even though the number of people passing through is only around 1.5 times larger. On top of this, the effect of countermeasures at other stations is strongly dependent on the number of commuters at the largest station.

Providing vital information to city health officials around the world, this study is among the first to show that only the largest hubs play such an extraordinary role.

The researchers also found the stations that are important for preventing an outbreak of infection in the population are not necessarily the same as those that are important for reducing the number of people infected.

This means that health officials must design different strategies for before a disease is identified and after it has begun to spread.



Commuter network of the Tokyo Metropolitan Area. Each circle corresponds to a station of the public transportation network, with colors indicating daily commuter numbers (black: < 1,000; blue: < 10,000; green: < 100,000; red: > 100,000). The study helps select stations offering the highest returns on disease-fighting investments.

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Evolution and Ecology Program

Collaborators

- Department of Evolutionary Studies of Biosystems, Graduate University for Advanced Studies, Japan
- Meiji Institute for Advanced Study of Mathematical Sciences, Meiji University, Japan

Informing European air quality policies

The Air Quality and Greenhouse Gases Program has provided the quantitative analysis for EU air quality policies since 1995, including the National Emissions Ceiling Directives, the Gothenburg Protocol revisions, and the Thematic Strategy on Air Pollution. In 2016, the EU reached a landmark agreement based on analyses using the program's Greenhouse Gas – Air Pollution Interactions and Synergies (GAINS) model, which will cut the health impacts of air pollution in half.

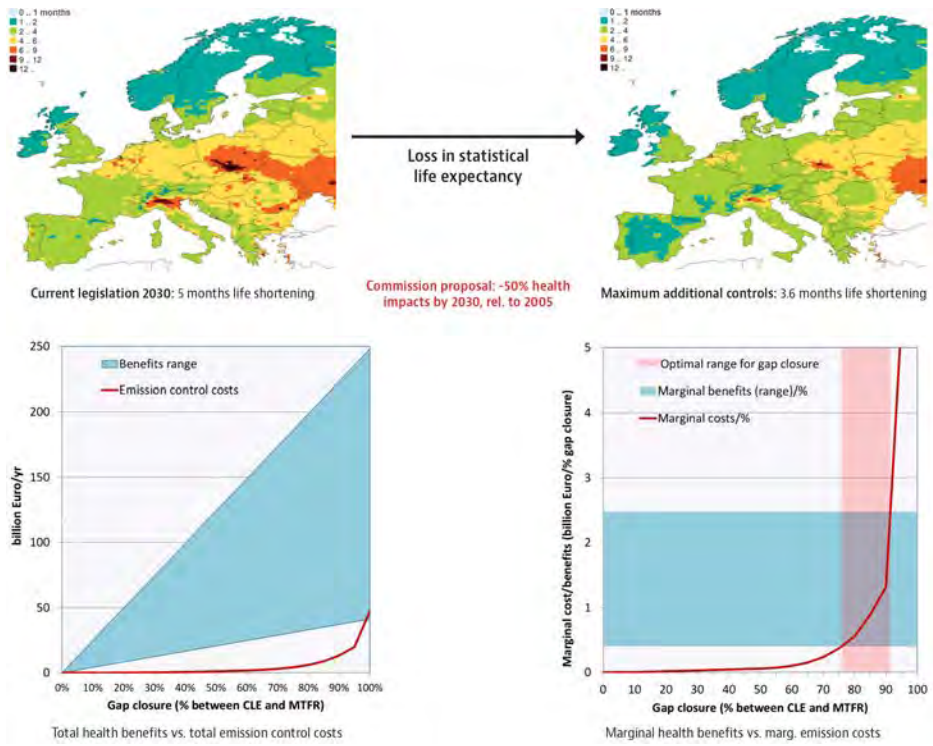
Extensive GAINS analyses of the costs and benefits of additional air pollution control measures and their impacts across EU member states and economic sectors formed the basis of the European Commission's "Clean Air Policy Package." This was a proposal for air quality legislation that would cut the health impacts of air pollution in the EU in half by 2030, compared to 2005, as well as reducing environmental impacts such as forest damage and biodiversity loss.

First presented by the Commission in 2013, the proposal was then discussed by the European Parliament and the European Council. While the political positions of the three institutions differed, for the first time ever they all agreed on the use of a common scientific tool: the IIASA GAINS model, as a shared knowledge base that feeds latest scientific findings into actual policy negotiations. To foster the acceptance of GAINS as a shared tool, the Air Quality and Greenhouse Gases Program hosted bilateral consultations with more than 100 experts of all 28 EU member states to review and improve the GAINS databases and align them with national information.

On request by the European Commission and the European Council, the program also produced a series of 17 policy reports that address critical issues on the potential and costs of further emission control measures (e.g., for transport, agriculture, and small combustion sources), and explore the implications of Europe-wide cost-effective strategies for reducing health impacts in the various member states and economic sectors. The reports also explain the GAINS methodology and input data.

In 2014, the European Parliament requested a specific study from IIASA to outline the impacts of the recently agreed climate policy targets on implementation costs of the proposed national emission ceilings for air pollution. In addition, the study explored economically rational adjustments of the ambition levels for air quality policies [1].

After extensive policy negotiations, in 2016 the three European institutions agreed on a compromise solution that establishes the upper limits for emissions of sulfur dioxide, nitrogen oxides, ammonia, volatile organic compounds, and fine particulate matter for each member state by 2030. This unprecedented agreement should reduce the health impacts from air pollution by 50% compared to 2005.



Total and marginal costs and benefits of further emission controls in the EU. The GAINS methodology identifies cost-effective portfolios of specific measures that improve local air quality and, at the same time, reduce global climate change. This approach, which focuses on actions that yield co-benefits at different spatial and temporal scales, provides a fresh perspective to clean air and climate policy development in many countries and world regions.

References

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Air Quality and Greenhouse Gases Program

Further information

EU Clean Air Policy Package

Collaborators

In the process of policy development, AIR cooperated with a wide network of national scientific institutions and researchers, many of them IIASA alumni, to jointly elaborate the methodologies and databases of the GAINS model. Key contributions were made from research organizations from IIASA member countries, including:

- National Institute for Public Health and the Environment, Netherlands
- IVL Swedish Environmental Research Institute, Sweden
- Norwegian Meteorological Institute (MET.NO), Norway
- Finnish Environment Institute (SYKE), Finland
- Centre for Ecology and Hydrology, UK
- Imperial College, UK
- European Commission Joint Research Centres, Italy and Spain

Can insurance effectively support climate resilience?

The application of insurance as a mechanism to help vulnerable people adapt to the impacts of climate change is gaining international recognition. In a review and discussion paper IIASA researchers support the idea but warn of potential problems.

In December 2016, negotiators at the Paris climate meeting adopted insurance as an instrument to aid climate adaptation. Earlier in the year, leaders of the Group of Seven (G7) had pledged to bring climate insurance to 400 million uninsured individuals in poor countries by 2020.

In their discussion paper, researchers from the IIASA Risk and Resilience Program welcome these developments, but also lay out the difficulties that policymakers will face in turning the ideas into action. They warn that ill-designed and poorly implemented insurance instruments could fail to reach the goals of negotiators, or worse, prove detrimental to the very people they are intended to protect. While insurance could provide funding to help people in need, the researchers point out several ways that such mechanisms could fail.

First, any new insurance scheme in developing countries needs to overcome difficult challenges, including lack of risk data, limited financial literacy, and weak financial infrastructure. Second, insurance for the poor will only be viable if it is linked to adaptation and risk reduction efforts that reduce the underlying risk factors. Climate-resilient infrastructure, adapted agricultural practices, and early warning systems must be included, otherwise climate insurance will be short-lived and far from cost-effective.

In addition, traditional insurance is an expensive mechanism with high transaction and capital costs, making premiums far higher than expected losses. This suggests that adaptation funds might be better spent on other types of safety net rather than on buying insurance cover from international markets. Insurance will also need high levels of subsidies or other forms of support to render it affordable and to avoid shifting responsibility on to those who are the least responsible for climate change, the least able to shoulder the premiums, and in many cases the least able to reduce their losses.

In order to avoid these problems, IIASA experts argue that policymakers should consider climate insurance as part of a wider adaptation strategy rather than in isolation or as an alternative to adaptation. When installing an insurance scheme, climate change and other factors contributing to the risks need to be taken into account. Also, insurance needs to be coupled with adaptation efforts to deal with these risk factors, otherwise it will be not be sustainable or cost-effective. What is critical for any adaptation or insurance scheme is that there is a good understanding of current and future risks from extreme weather. This is where the experience and tools for risk assessment assembled by risk research will be instrumental.

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Risk and Resilience Program

Collaborators

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Water security in Asia

The Asian Water Development Outlook report, published by the Asian Development Bank, provides an overview of the water security status of 48 countries of the Asian-Pacific regions. This critical report, which had substantial input from the IIASA Water Futures and Solutions Initiative, depicted possible Asian water futures, identified hotspots of water insecurity, and proposed solutions to cope with these threats.

To explore how water supply and demand will change in the decades to come, the IIASA Water Futures and Solutions Initiative developed a set of possible future scenarios for Asian-Pacific areas. These are based on the Shared Socioeconomic Pathways, which describe possible paths human societies could follow over the next century, along with the Representative Concentration Pathways, which are greenhouse gas concentration trajectories. These pathways were developed for the Intergovernmental Panel on Climate Change assessments and are used as the foundation for much of the world's global change modeling.

For the Asian Water Development Outlook 2016 report, three scenarios were explored:

- The sustainability scenario
- The middle of the road scenario
- The regional rivalry scenario

For the sustainability scenario, barriers to achieving sustainability, mitigation, and adaptation are minimal, in the middle of the Road scenario they are intemediate, and for regional rivalry they are high.

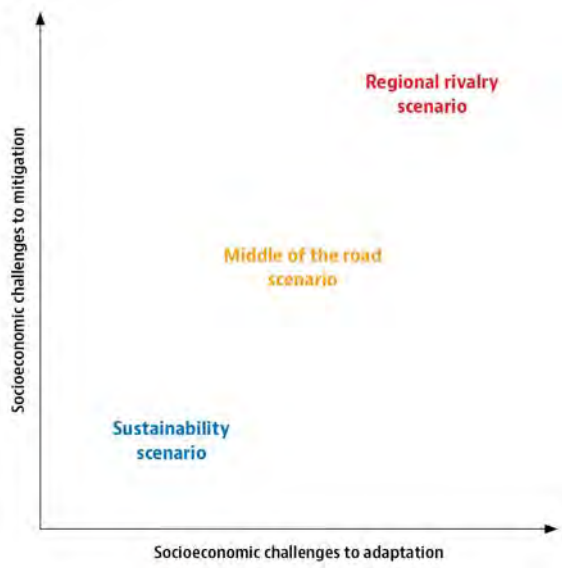

Figure 1: Scenario dimension for Asian-Pacific water futures.

The scenarios incorporate the considerable changes to Asia's population that are expected in the coming decades. Asia's total population was around 3.8 billion in 2010, and will grow to between 4.3 and 5.1 billion by the 2050s, depending on the scenario used. GDP per capita will increase in all combinations of scenarios and regions, however, total GDP may decrease in some regions such as East Asia and countries with advanced economies, all of which have implications for water use and demand.

Three state–of-the-art water models were used to calculate water demand for the agricultural, industrial, and domestic sectors, based on socioeconomic and climate changes. The researchers estimated that current Asian water demand (2,410 km3/year) would rise by about 30–40% to 3,170-3,460 km /year in the 2050s under the three scenarios considered. At the regional scale, South Asia and East Asia remain the largest water users in the continent in all sectors until 2050, and significant rises in agricultural demand are also expected in Central and West Asia.

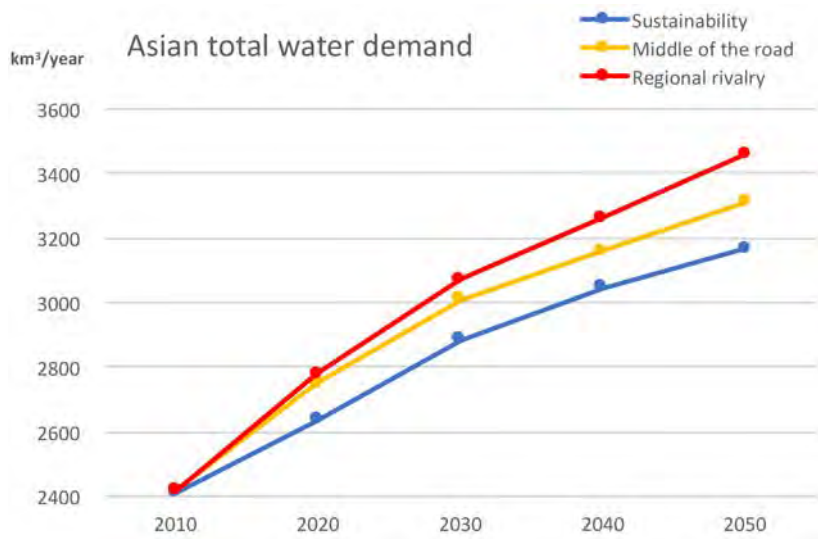

Figure 2: Total Asian-Pacific water demand projection

This study also assessed imbalance between water demand and supply, highlighting hotspots of water scarcity. Many countries in Asia, including, Afghanistan, Armenia, China, Pakistan, and Uzbekistan already experience pervasive water scarcity conditions. At present, almost all countries in central and West Asia, East Asia, South Asia, and parts of Southeast Asia have regions that suffer from severe water scarcity for at least one month every year.

Future projections indicate that the areas under severe water scarcity conditions in Asia will grow, especially in regions that are already hotspots for water scarcity, creating greater imbalances. Under all scenarios the number of people living in severely water scarce areas will increase from 1.2 billion to 1.7–2.1 billion, approximately 40% of Asia's future population. The largest share of affected people will be mainly in South Asia, followed by East Asia.

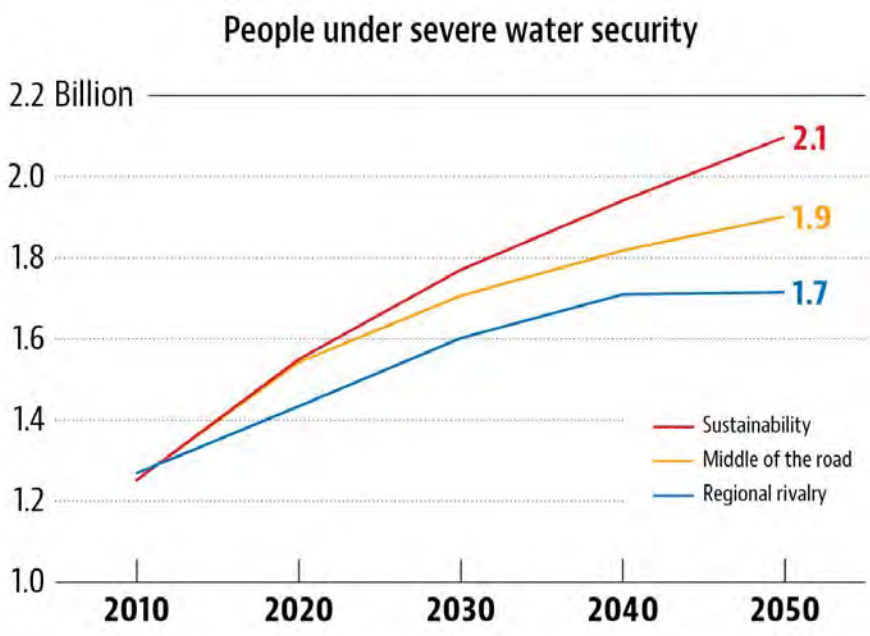

Figure 3: Asian-Pacific future population living in severe water scarce areas

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Water Futures and Solutions Initiative

Collaborators

Yasmin Siddiqi, Asian Development Bank

Exploring the new phenomenon of economic platforms

Businesses that provide "platforms"—such as an app store for mobile phones—allow other companies to build on them, and connect to a network of consumers. This powerful structure is still an emerging phenomenon but has the potential to transform economies. The Platform Value Now project brings together researchers and national policy advisors in Finland to jointly develop a policy to support such businesses as a key part of the nation's economy.

A platform is a foundation on which others can stand, and the same is true in economics. If you build a digital platform, for instance, other businesses can easily connect their business with yours and build products and services on top of it. Take Apple or Android, their real success is not from features or functions, it is from the app store which allows external developers to create value. The *Platform Value Now* project, funded by the Finnish Strategic Research Council, focuses on understanding these emerging platform structures and how they could work in the Finnish economy.

The typical features of the current platform companies are: a global nature, extremely fast growth, and lots of interest from investors. Companies such as Amazon, Airbnb, and Uber are operating globally and collecting a large share of the value generated.

Currently, 80% of platform businesses are American and 80% of these are located in California. The recent developments indicate that those companies that are fast to join existing platforms or initiate platforms themselves are starting to dominate, making it difficult for others to get into the market. For a policymaker in Finland, or anywhere outside the USA, the challenge is that the value staying in the country is currently small, and it therefore does not support local employment.

The potential impact on public funding is even more serious, because a large amount of the taxable income is transferred to another country. To assess the impact of this, IIASA researchers have developed methods to measure the un-captured GDP, that is, the share that is lost to platform companies operating from other countries [1][2].

As part of the project, IIASA researchers have analyzed platform policies in different countries and alternative government roles and options. These were part of a special report on global scenarios and alternative pathways of platform economy development, which contributed to the prime minister's strategic development project: *the Road Map of the Finnish Platform Economy*, to be published in 2017.

The project continues to collaborate closely with the team of senior civil servants that are responsible for platform economy development in the Corporate Steering Unit of the Finnish Ministry of Employment and the Economy.

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Advanced Systems Analysis Program

Collaborators

- Aalto University, Finland
- Stevens Institute of Technology, USA
- University of Jyvaskyla, Finland

Achieving sustainable agriculture

Sunny Forest | Shutterstock

The Global Agro-ecological Zones (GAEZ) system, developed by IIASA and the UN Food and Agriculture organization (FAO), provides policymakers with comprehensive information for rational land use planning. In 2016 the system was updated and used in many countries in Asia and Africa to aid governments in improving their food security and agricultural development.

GAEZ estimates show that 70% of global water withdrawals go to agriculture and as much as 90% of fresh water use is for irrigation. Global net crop irrigation requirements will likely increase by 15-23%above 2010 levels because of climate change and expansion of irrigated areas. However, in many regions an increase of irrigation water withdrawal can be avoided or mitigated by improving the efficiency of irrigation systems and better water and land use management.

GAEZ work has resulted in collaborations around the world, including 2016 projects in Bangladesh, India, Ghana, and Thailand. In Thailand, IIASA collaborated on the project "National Agro-economic Zoning for Major Crops in Thailand," helping to strengthen national capacity for addressing issues of land use and land planning and the sustainable management of natural resources through the establishment of agro-economic zones.

In South Africa, in collaboration with the World Wide Fund for Nature, IIASA used GAEZ to examine the potential availability of sustainable feedstock resources for producing renewable airline fuels in sub-Saharan Africa. The extended GAEZ included additional feedstock crops (including Solaris tobacco and the oil seed plants Camelina and Triticale) and assessed the potential for using them to produce airline fuels while taking into account food security requirements and environmental protection.

The latest GAEZ (version 4) includes updated information on land cover, crop areas, protected areas, renewable water resources, and climatic conditions for the historical period 1961-2010 and for a selection of future climate simulations. The FAO's water balance and accounting model GlobeWat has also been expanded and integrated into GAEZ v4.

In 2016, work also focused on completing the preparation of the GAEZ data portal for release. The data portal will help ensure that UN member countries have sufficient, reliable information on sustainable management of natural resources for food and agriculture to support policy decisions at all scales. The portal provides free and easy internet access to data and information.

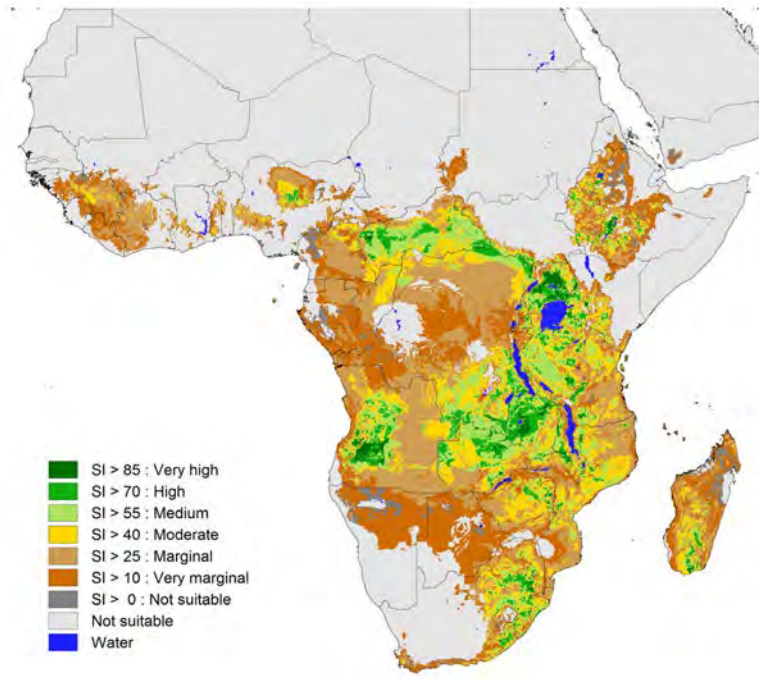

Figure 1: Agro-ecological suitability of rain-fed Solaris tobacco (biofuel feedstock) simulated using GAEZ

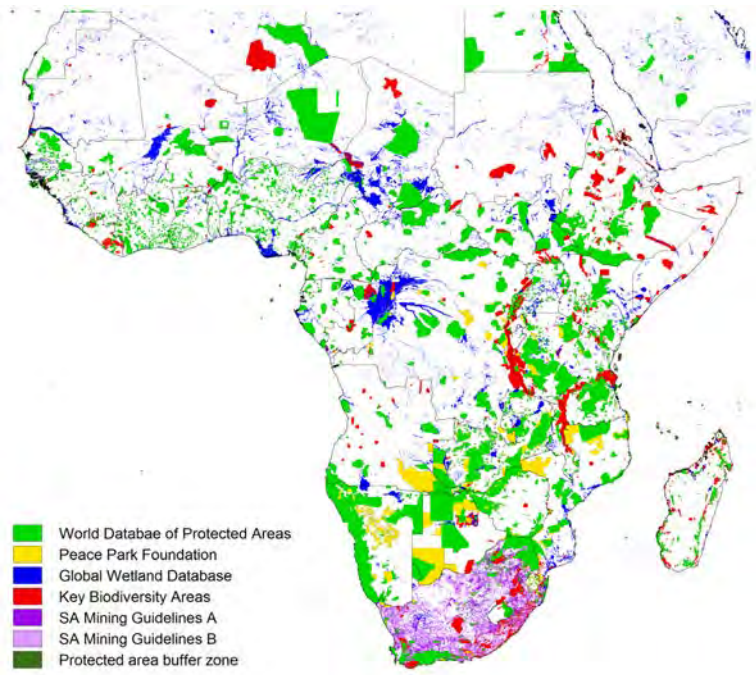

Figure 2: Distribution of 'no go' areas applied in the assessment sustainable biofuel feedstock production in sub-Saharan Africa.

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Water Program

Collaborators

- Food and Agriculture Organization of the UN
- World Wide Fund for Nature South Africa
- Institute of Rural Management Anand, India
- National institute of Hydrology, India
- Centre for Water Resources Development and Management, India Shanghai Climate Center, China
- University of Maryland, Department of Geography, USA

Further information

GAEZ v.4 and FAO-GAEZ Data Portal

Rethinking expert engagement in participatory processes

IIASA scientists have developed and tested a new way for disaster-risk experts to engage in participatory and deliberative processes, differing significantly from their traditional role of simply providing policymakers with technical solutions. In the new method landslide experts interactively developed risk protection options that corresponded to the different perspectives of the stakeholders. As a result, experts and stakeholders were able to co-produce useable knowledge.

The unique participatory process, developed by the IIASA Risk and Resilience Program, was designed to reduce landslide risk in the highly exposed Italian town of Nocera Inferiore. The process, along with the complementary scientific risk analyses and decision tools, was presented in a 2016 special issue of the journal *Natural Hazards* entitled *Rethinking participatory processes: the case of landslide risk in Nocera Inferiore* [1].

The three-year participatory process, described in [2], was carried out in a town where public opposition to an expert-proposed landslide risk mitigation project had resulted in a stalemate. Under the new approach, citizens and experts co-produced landslide risk mitigation options. The main difference in this case, compared with other analytic-deliberative processes, was its explicit elicitation of multiple stakeholder perspectives on the nature of the problem and its solution.

The process began, as described in [3], with experts identifying three distinctly different discourses, reflecting the varying views of the community: “safety first” with emphasis on a mix of active and passive structural measures; “careful stewardship of the mountain” requiring (mainly) natural measures like a belt of trees to actively stop the landslide, and “rational choice” with emphasis on the opportunity costs of all measures and the need for informed individual choice, for instance, in the construction of homes.

The expert support, which also included quantitative risk analysis and cost-benefit analysis, took these different stakeholder perspectives into account in the design of policy options. A final unique feature of the process was the aim of compromise rather than consensus. Instead of working towards a full agreement on the problem and its “best” solution, the participants forged a compromise, recognizing that there are multiple ways to view a problem and the “best” solutions.

Experts produced three technical options that reflected these distinct views and at the same time complied with Italian law requiring a high degree of safety in public landslide investments. The measures ranged from structural storage basins that passively block the path of the landslide, rills and forestation that actively prevent landslides, and warning systems that reduce the consequences. The options were discussed and refined by participants and experts in the deliberative process until they adequately reflected the “contested terrain”. This served as the basis for negotiating a compromise. The provision of multiple co-produced policy options enhanced stakeholder deliberation by respecting legitimate differences in values and worldviews.

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Risk and Resilience Program

Loss and damage in the Arctic under climate change

IIASA researchers have reviewed the latest studies on the impacts that climate change will have on the Arctic, from its delicate environment to its local communities. The results show that some changes will be so sweeping that they may go beyond the bounds of adaptation, and a case can be made for international support for the victims of this climate-related loss and damage.

Climate change will have severe impacts on the Arctic, both scientific evidence and traditional knowledge show, and those risks and impacts may also have global consequences. To assess exactly what those impacts might be, an IIASA researcher reviewed the latest studies on the consequences of climate change for the Arctic region and their implications for identifying risks beyond adaptation and supporting the victims of climate-related loss and damage.

Climate related risks and impacts are not distributed equally in the Arctic, the review revealed. And although some Arctic countries have high adaptive capacity, under conditions of rapid change current institutions and government mechanisms are not sufficient to deal with the multiple challenges of change, which include climate change, environmental degradation, and the pressure of new businesses coming to the Arctic.

Another key finding was that climate change increases the vulnerability of local and indigenous communities across the region. Land-based livelihoods, such as reindeer husbandry, can be affected by climate change directly because of shrub growth, which absorb heat more than snow or ice, and will exacerbate regional warming. Livelihoods can also be indirectly affected by increased economic interest in exploitation of natural resources, which can lead to land-use conflicts. Sea-level rise and coastal erosion are also forcing people to emigrate or relocate away from coastal communities. This can have negative impacts on society and culture, and raises questions about the limits to adaptation.

One important issue the review highlighted is the lack of local capacity or an international institutional framework to organize relocation. As people have to move away from their communities many feel this can no longer be classed as 'adaptation' and therefore should be considered loss and damage worthy of support by the international community. Relocation can also have multiple negative consequences, especially in indigenous communities who are facing loss of their traditional livelihoods and culture.

There is a need for (re-)identification of roles and responsibilities in international climate policy, especially in terms of liability and compensation mechanisms and international institutional support to define the limits of adaptation, the review concluded.

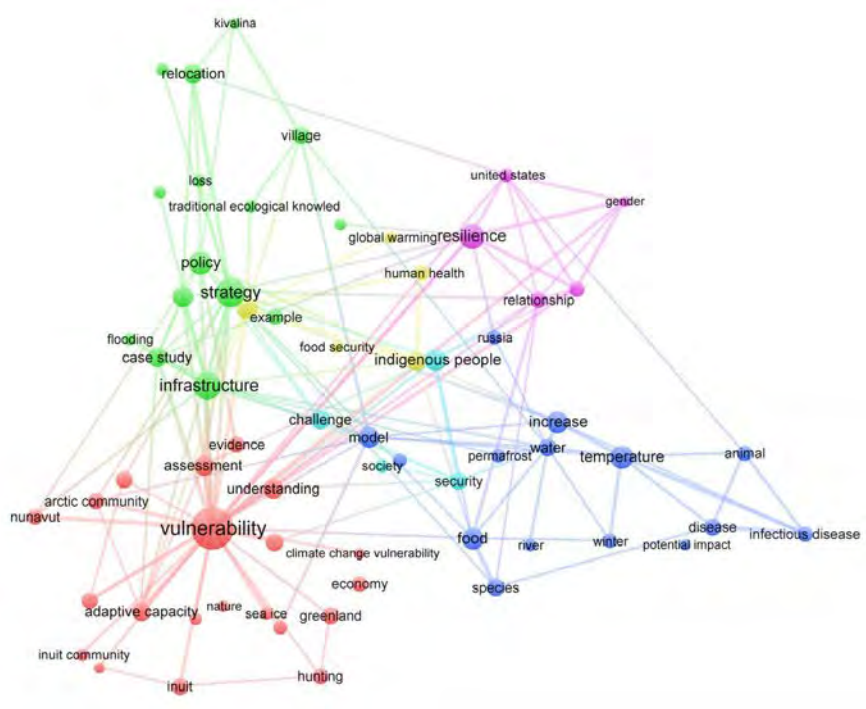

Figure: *Arctic loss and damage-related studies as a "keyword mining" visualization. The 'term map' visualizes main topics found in the articles. The figure shows the essential keywords related to the Arctic loss and damage topic that are most frequently encountered, extracted from the article titles and abstracts. Overall 83 terms that met the threshold of appearance 10 times were selected. The size of the circles indicates frequencies of keywords. Circle colors indicate close relatedness of the terms (substance-wise). The terms marked with the same color form a cluster of related terms that can be seen as a topic. Lines express co-occurrence of the terms between the clusters either in the article title, or abstract, or both (N=164). Created by Maria Söderholm from Aalto University, Finland.*

Arctic Futures Initiative

Collaborators

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- Fondazione Eni Enrico Mattei, Italy
- Basque Centre for Climate Change, Spain
- University of Oxford, UK
- Institute for Environmental Studies, Vrije Universiteit Amsterdam, Netherlands
- University of Salzburg, Austria
- University of Wellington, New Zealand
- International Center for Climate Change and Development, Bangladesh
- Practical Action, UK
- UN University, Institute for Environment and Human Security, Germany
- Climate Analytics, Germany
- University of Graz, Austria
- Vienna University of Economics and Business, Austria University of Vienna, Austria
- Universität Zürich, Switzerland
- University of Helsinki, Finland
- Aalto University, Finland

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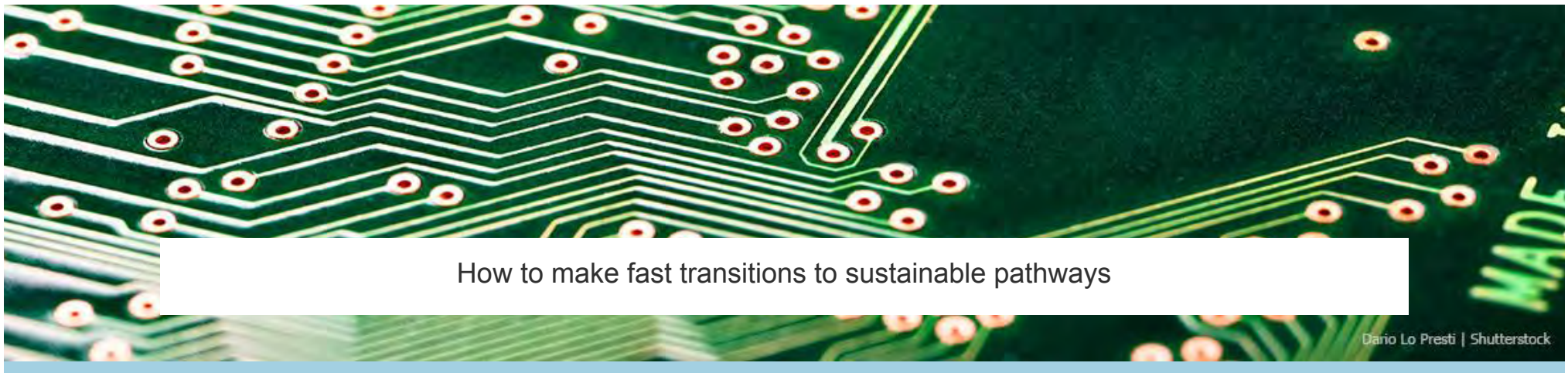
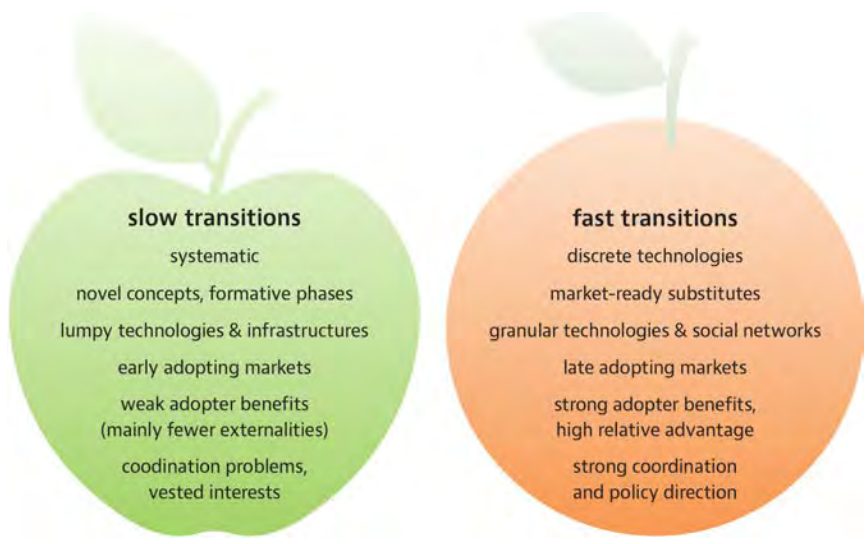

Dario Lo Presti | Shutterstock

How to make fast transitions to sustainable pathways

Why do some societal and technological transitions happen relatively rapidly, in a decade or two, while others take a century? This question is vital, since achieving the UN Sustainable Development Goals (SDGs) and meeting climate targets will require rapid transitions to sustainability. In a 2016 review paper, the IIASA Transitions to New Technologies Program set out to find the answers.

There is a mismatch between the ambitious timing of the SDGs—which call for major transformational change within a few decades—and the historical evidence, which shows comparable transformative changes have taken up to a century.



A novel taxonomy of determining factors that can explain differences in transition speeds between different transition processes and technological systems ("apples" and "oranges"), which also suggests innovation and policy options for accelerating the much-needed transitions towards sustainability.

The IIASA review paper, published in the journal *Energy Research and Social Science,* was the first to propose a systemic taxonomy of determining factors that can explain why certain transitions happen fast (one to two decades) whereas others proceed slowly (several decades up to a century) [1].

Fast transitions tend to have, among other things, strong coordination and policy direction, along with substantial benefits for adopters. The characteristics of slower transitions include weaker adopter benefits and poor coordination, along with vested interests (see figure for full lists).

The new systemic taxonomy helps to explain differences between "apples" and "oranges", in other words completely different processes and technological systems that cannot be compared without all other things being equal. The findings also provide useful insight for crafting policies and novel technology system configurations to accelerate the multiple social, institutional, and technological transitions needed for the transition to sustainability.

This research integrates a number of novel research streams conducted within the Transitions to New Technologies Program, including work on the development phases of technological innovation; agent-based modeling of technological interrelatedness and complexity; social network and peer effects; and spatial spillover effects in the international diffusion of new technologies [2][3][4].

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Transitions to New Technologies Program

Collaborators

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Economic cooperation between the EU and Eurasian Economic Union

Deep, comprehensive, long-term economic cooperation between the EU, the Eurasian Economic Union (EAEU), and their neighbors was the focus of the pilot phase of an IIASA project that concluded in 2016. The project, which brought together an international group of economists, modelers, and other experts, fostered constructive dialogue on the multiple facets of how such cooperation might work.

Relations between the EU and Russia would need to be much improved for the enhanced EU-EAEU economic cooperation to become a realistic proposition. However, setting aside the present political tensions, the IIASA project *Challenges and Opportunities of Economic Integration within a wider European and Eurasian Space* takes the standpoint that all sides would benefit from "Lisbon-to-Vladivostok" economic cooperation. To prepare for this, the project has brought together officials and experts to have a constructive dialogue about the opportunities and challenges of any economic partnership.

Many dimensions need to be considered, ranging from trade in goods and services to the free movement of capital and people, including facilitating visas and residence permits, the development of trans-border transport infrastructure, revised regulations for intellectual property rights, government procurement, and policies for state-owned companies.

The project identified several key facets that should be considered, including trade regimes and extending the deal beyond a traditional free-trade area; energy security; transport and infrastructure; and the mobility of people. Any research on this topic must go beyond estimating short-term, direct trade effects and extend to long-term, indirect effects, the project participants concluded. Especially those related to "non-tariff barriers"—such as sanitary or veterinary regulations and customs administration. These can have significant economic impacts and implications.

There is a fundamental reciprocal interest in energy security for the EU and EAEU. For the EU, this means supply security (source security, transit security, and fair and predictable prices); for Kazakhstan and Russia it is demand security (financial and economic security, and fair and predictable prices); and for transit countries it is the stability of revenues and supplies.

Transport networks (both road and railway) should be further developed in the near future, and the potential for common electric power markets, pipeline systems, and trans-continental fiber-optic links should also be explored. Adequate regulatory frameworks, security, and investments are key for both transport and infrastructure.

To ensure the mobility of business people, experts, and professionals, efficient visa and residence permit procedures are needed, along with the mutual recognition of qualifications. These steps can eventually lead to a visa-free regime with large-scale academic exchanges. However, the project participants do caution against prematurely raising the issue of the labor migration in the EU-EAEU context.

Another important topic discussed by project experts was the future of trade and economic relations between the EU, the EAEU, and Ukraine, Moldova, and Georgia—three states that have already concluded deep and comprehensive free trade agreements with the EU. The development of EU-EAEU relations will require constructive negotiations on a fair trade policy between Ukraine, Moldova, Georgia, and the EAEU, with the participation of the EU to ensure the compatibility of the EU-EAEU cooperation deals.

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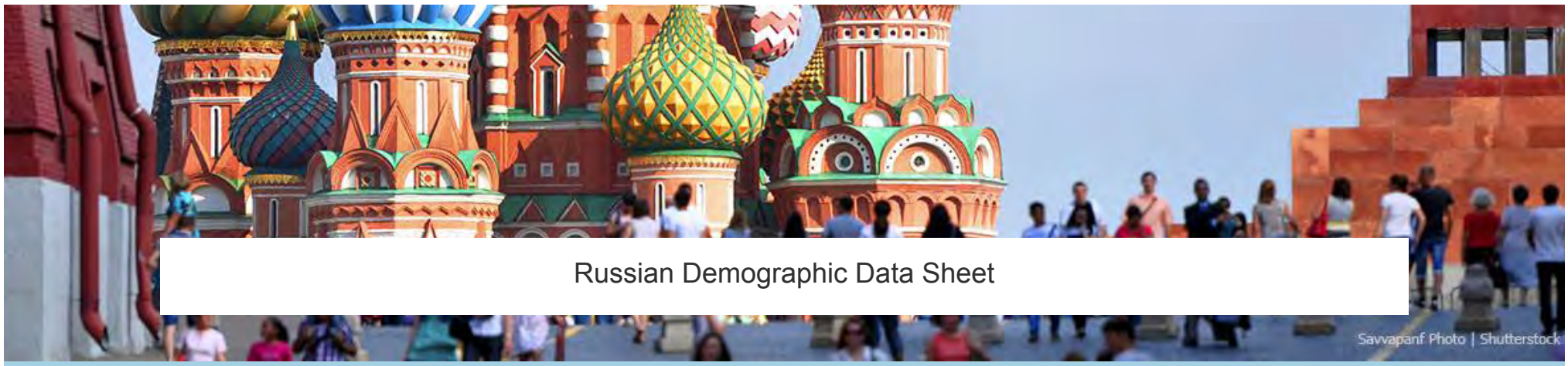
Challenges and Opportunities of Economic Integration within a Wider European and Eurasian Space



Russian Demographic Data Sheet

The IIASA Russian Demographic Data Sheet 2016 reviews key population trends in Russia, and gives a population projection for the country for 2035. The sheet allows experts to analyze the country's regional demography and demographic processes.

The Russian Demographic Data Sheet 2016, available in Russian and English, uses a number of the latest demographic indicators regarding population growth and aging, many of which were calculated for Russia for the first time. Led by World Population Program Deputy Director Sergei Scherbov, the sheet uses cutting-edge mortality, fertility, and migration models—more sophisticated than previously available. These were used by the researchers to evaluate age-specific transitions and transition rates based on the aggregate scenario definitions prepared by the Russian Federal State Statistics organization.

A unique feature of the data sheet is the introduction of new measures of aging, developed at IIASA. These include the "prospective old-age dependency ratio." The traditional old age dependency ratio relates the number of "old-age dependents," who are assumed to be everyone 65+ years old, to those assumed to support them, people from 20–64. However, rather than assuming everyone over 65 is dependent, the prospective old-age dependency ratio defines an old-age dependent as someone with a remaining life expectancy of 15 years or less. Variation in the number of individuals with a remaining life expectancy of 15 years or less was calculated for each region of Russia, and presented for the first time.

Additionally, a zero-migration scenario was also introduced. It allowed evaluation of the consequences of internal and external migration on population size and composition in regions within Russia. The zero-migration scenario led to a population reduction of about 4% by 2035 compared to contemporary population size, while the scenario including migration led to a basically unchanged population size.

The data sheet was presented at the high-level Gaidar Forum in January 2017 in Moscow. In a dedicated session at the conference, Scherbov presented the methodological background of the applied new methods and the major results to journalists, scientists, and policymakers from across Russia.

The Russian Demographic Data Sheet presentation and panel discussion at the Gaidar Forum. From left to right: Tatyana Maleva (director at the Institute of Social Analysis and Forecasts), Sergei Scherbov (IIASA World Population Program Program deputy director), Professor Dr. Pavel Kabat (IIASA director general and CEO), Wolfgang Lutz (IIASA World Population Program director), Konstantin Laykam (deputy head of the Federal Service of State Statistics), and Valery Yelizarov (head of the Center for Population Studies, Lomonosov Moscow State University).

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World Population Program

Collaborators

- Russian Presidential Academy of National Economy and Public Administration
- Russian Federal State Statistics Service

Further information

- The research was conducted in the framework of the ERC funded Reassessing Aging from a Population Perspective (Re-Aging) project (under Grant ERC2012-AdG 323947-Re-Ageing).
- IIASA at the Gaidar Forum 2017

Labor market and migration across Eurasia

Samet Guler | Shutterstock

The impact of migration flows on the sustainable development of Eurasia, labor market challenges, and the harmonization of education systems in the EU and the Eurasian Economic Union (EAEU) are complex and controversial topics. In 2016, IIASA provided the only platform to date that has brought together experts and policymakers from East and West to discuss these issues.

The workshop, part of the IIASA project *Challenges and Opportunities of Economic Integration within a Wider European and Eurasian Space*, was attended by over 50 well-established academics and policymakers from Europe, the post-Soviet space, Turkey, the Republic of Korea, and the USA. The participants discussed possible scenarios of cross-border migration (both labor migration and refugee flows) and the changing structure of the labor force, as well as their economic and social implications for the labor markets and the economic growth of both the source and host countries in the EU, the EAEU, and the countries in their joint neighborhood. They also considered practical aspects such as the prospects of introducing a visa-free regime between the EU and the EAEU, enhancing the reciprocal recognition of labor migrants' pension rights between countries, fostering educational and academic exchanges, and the mutual recognition of diplomas [1].

At a high-level panel session, participants reflected on the long-term prospects of economic cooperation between the EAEU, the enlarged EU, and their neighbors, including the key Asian players such as China, Japan, the Republic of Korea, as well as the USA, focusing on labor market challenges and the impacts of migration flows on the sustainable development of the Greater Eurasian region.

The session was chaired by Pavel Kabat and included talks by Tatyana Valovaya, Václav Klaus, Jeffrey D. Sachs and Péter Balás, as well as Evgeny Vinokurov, Peter Havlik and Jesus Crespo Cuaresma.

Evgeny Vinokurov (Senior Research Scholar, Advanced Systems Analysis Program, IIASA), H.E. Tatyana D. Valovaya (Member of the Board – Minister in charge of Integration and Macroeconomics of the Eurasian Economic Commission), and Professor Dr. Pavel Kabat (Director General and CEO, IIASA)

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Challenges and Opportunities of Economic Integration within a Wider European and Eurasian Space

Education and training

IIASA continues to strengthen researchers' knowledge and abilities in systems analysis, both by training early-career researchers, and demonstrsting its integrated models in workshops around the world. The Young Scientists Summer Program and Postdoctoral Programs in particular provide vital capacity building.

Young Scientists Summer Program

The flagship Young Scientists Summer Program (YSSP) allows around 50-55 PhD students to work along IIASA reserchers for three months every summer. Participants prepare a research paper during the summer, many of which are published in prestigious journals. In 2016 there were 51 participants from 25 countries who spent the summer of 2016 in Laxenburg working on their research projects in IIASA programs.

- 2016 participant list
- Biosketches and abstracts
- YSSP Final Colloquium

Postdocs

The Postdoctoral Program allows early–career scientists to research a topic related to the scientific agenda at IIASA and hone their skills in systems analysis. In 2016 there were a total of 18 postdoctoral researchers, and several national member organizations have recently partnered with IIASA to fund postdocs from their countries. In 2016 bilateral deals for funding postdocs at IIASA were reached with Brazil, Mexico, and the Republic of Korea. As a result, applications to the program surged from 59 in 2015 to 276 in 2016 and nine new postdocs from these countries will start at IIASA in 2017. Such schemes not only benefit the individual postdoc scholars, but also contribute to developing expertise in system analysis among a country's researchers.

2016 award winners

The Peccei Award, in recognition of rigorous research, and the Mikhalevich Award, given to students who use mathematical tools to solve real-world questions, are awarded every year to outstanding young scientists participating in the YSSP. They allow the winners to return to IIASA for another three months.

The winner of the Peccei Award with honors was César Terrer. A PhD student at Imperial College London, UK, Terrer won the award for his final paper: "Global Consequences of Nitrogen-Mycorrhizal Effects on the Land C Sink Under Rising CO_2." Terrer worked in the Ecosystems Services and Management Program during his three -month stay at IIASA.

Clara Orthofer also received a Peccei Award for her paper entitled: "Shale gas & South Africa's energy future – too costly, too late?". A PhD candidate at the Electrical Engineering Graduate School of the Technical University of Munich, Orthofer spent her summer in the IIASA Energy Program.

The Mikhalevich Award with honors went to Marcus Thomson from the USA for his paper on "Climate, Corn, and Culture: Simulated Impact of Paeloclimate Change on Fremont Native American Maize Farming in Utah". Thomson, a PhD candidate at the University of California, worked in the Ecosystems Services and Management Program at IIASA.

Postdocs at IIASA in 2016

Artem Baklanov (ASA, Russia) analyzed social dilemmas using a game-theoretic approach and explored how a small change in the 'boundedness' of rationality influences the properties of the Nash equilibrium.

Peter Bednarik (EEP, RISK, Austria) designed a computer game based on the forestry sector, and used it to investigate the conditions under which a "tragedy of the commons" would be avoided.

Gergely Boza (EEP, Hungary) worked on two projects; the first examining the strategies plants use to influence microorganisms inhabiting their root systems and the second focusing on evolution and stability of human cooperative behavior.

Edward Byers (ENE, TNT, WAT, UK) investigated the impacts and risks of climate change on energy systems and infrastructure at a global scale to identify hotspots of risk.

Fulvio Di Fulvio (ESM, Italy) focused on mapping global forest resources and calculating the costs of supplying wood biomass for both material and energy uses.

Adam French (ASA, RISK, USA) examined the potential for watersheds in the water-stressed Global South to switch to Integrated Water Resource Management—an integrated, multi-sectoral form of water governance.

Fei Guo (AIR, ENE, China) used a bottom-up mathematical model to project energy consumption in residential buildings in China, and to simulate intervention effects of incentive policies.

Daniel Jessie (ASA, USA) analyzed social dilemmas using a game-theoretic approach and suggested a new way to uniquely decompose a game into the portion that encourages individuals to seek personally preferred payoffs and the portion that requires cooperation among players.

Wei Qi also received a Mikalevich Award for his paper "Simplifying the complex: Alternative measures of bilateral migration," which was a result of his stay at the IIASA World Population Program. Qi is a PhD student at Institute of Geographic Science and Natural Resources Research, Chinese Academy of Sciences.

Luzma Fabiola Nava Jiménez (WAT, Mexico) examined the watergovernance regime in river basins which cross the USA/ Mexico border.

Christina Kaiser (EEP, Austria) studied competitive and synergistic interactions between soil microbes belonging to different microbial functional groups in a spatially structured system.

Mia Landauer (RISK, AFI, Finland) studied the implications of loss and damage from climate change, and participatory risk governance of projects in the Arctic.

Luciano Mendes (AIR, ESM, Brazil) embarked on two projects linked to reducing agricultural pollution and optimizing resource use on farms.

Sennai Mesfun (ESM, Eritrea) studied the impact of prolonged adverse weather events in power systems with high share of renewable sources.

Piera Patrizio (ESM, Italy) used spatially explicit models to explore the economic feasibility of the industrial sector investing in carbon mitigation solutions.

Henrik Sjödin (EEP, Sweden) used mathematical models to show how migration between groups can transform simple, non-cooperative communities into highly cooperative ones.

Matthias Wildemeersch (ASA, ESM, Belgium) used network theory to develop early-warning signals and anticipatory management strategies for pest outbreaks in ecosystems.

Sam Hyun Yoo (POP, Republic of Korea) demonstrated that delayed childbearing as well as a reduced number of births per woman is affecting fertility in the Republic of Korea.

Shaohui Zhang (AIR, ENE, China) examined energy efficiency improvements in Chinese industry at various scales, and the resultant emissions savings.

Map showing the diverse array of nationalities of IIASA postdocs and participants of the Young Scientist Summer Program; member countries are highlighted in blue. The interactive online version gives a full list of participants for each country.

Southern African Systems Analysis Centre

Building on the success of the IIASA Southern African Young Scientists Summer Program, which ran from 2012-15, the South African National Research Foundation and the country's Department of Science and Technology, in collaboration with IIASA, created the new Southern African Systems Analysis Centre (SASAC) to expand systems analysis capacity development in the region.

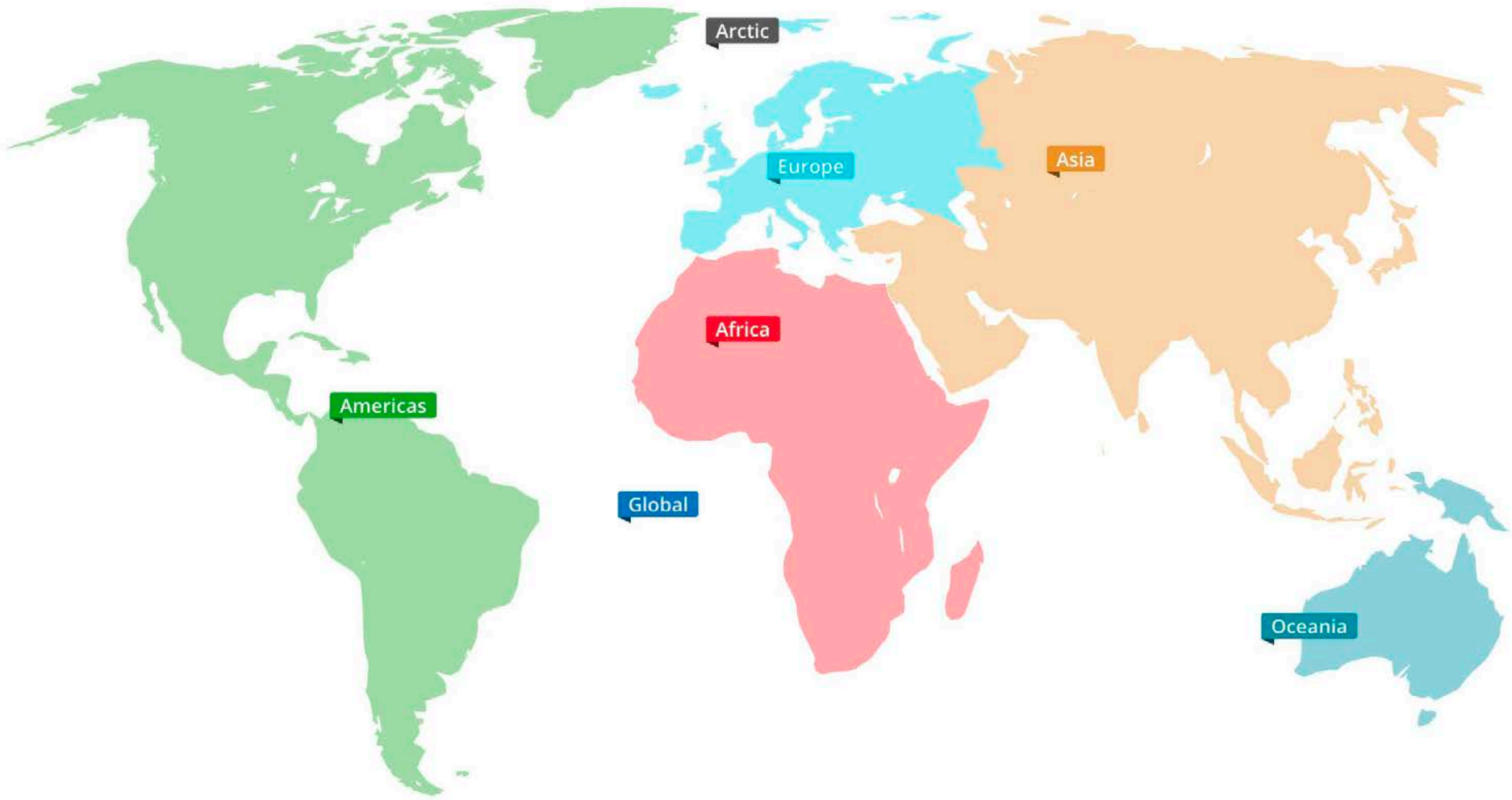
Launched in 2016, SASAC provides a dedicated bursary program for South African PhD students based at South African universities to complete their studies with a supervisor experienced in systems analysis. A total of 19 PhD students enrolled in 2016, and as well as visiting IIASA for the chance to learn more about the institute and its research, they were given two months of dedicated training in systems analysis at two South African universities. In addition, 28 early-career researchers had the opportunity to attend a capacity-strengthening program, which included a short course and presentations contributed by IIASA.

Building systems analysis expertise

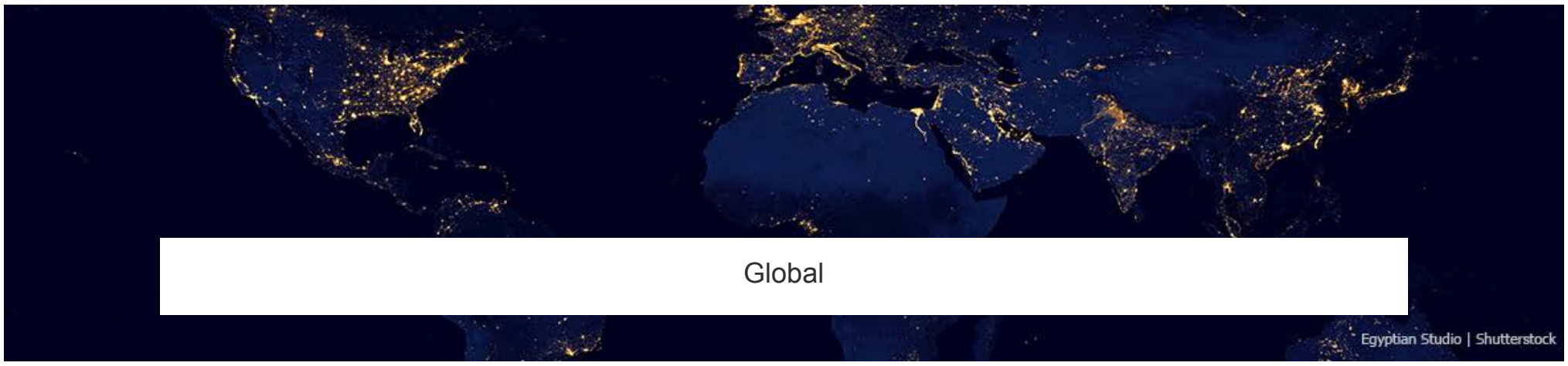
In 2016, IIASA scientists hosted or coordinated 92 events worldwide, including a number of workshops and activities designed to build capacity in systems analysis. Below is a small selection of these activities.

- Workshop on Multi-Model Integration, IIASA
- Workshop on Global Carbon Mapping with the Global Carbon Project and the World Urban Database and Access Portal Tools organization, Switzerland
- Dialogue session with Fischer, Halonen, and young scientists: World Leaders and future thought leaders, IIASA
- EU-African Union-IIASA Evidence and Policy Event, Italy
- Visit of young scientists from Russian universities, IIASA
- 3-week "High-level Capacity Strengthening Programme", South Africa

Global, regional, national



IIASA research spans the globe, providing vital scientific evidence at national, regional, and global scales. The interactive online version of this map allows readers to explore different regions to read highlights of IIASA work and collaborations in different areas and at different scales.



Global

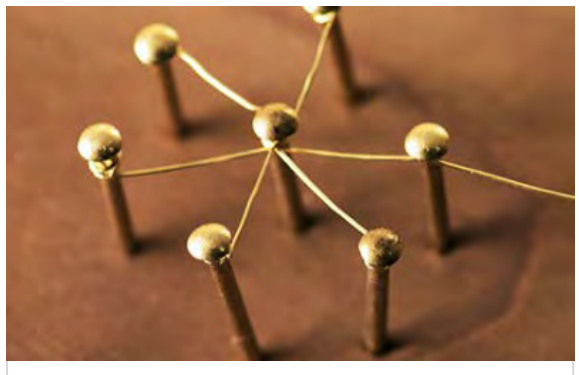
Many of the challenges we face today cannot be tackled by a single region or nation, but will require global action. IIASA research spans issues that must be dealt with at a global scale, from climate and trade to water and food security.

Selected highlights

New ways to measure age and aging

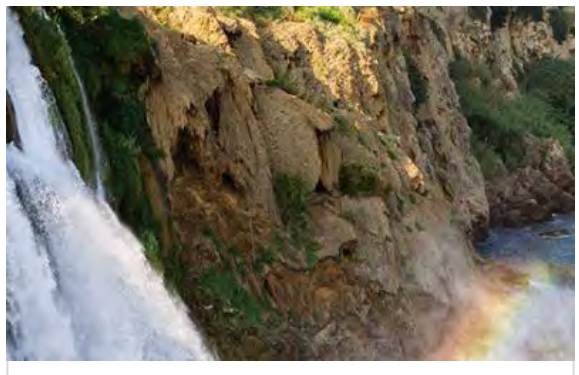
Resilience of the global trade networks

Reducing water stress worldwide



Reducing the risk of financial crisis

Untangling uncertainty for disaster risk projections

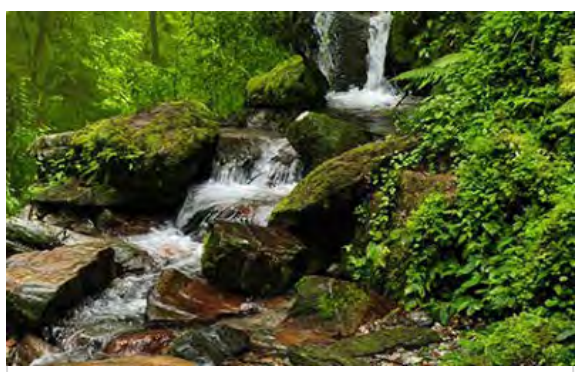


Modeling global water use for the 21st century

Modeling disease eradication

Using carbon markets to tackle climate change and protect forests

Using game theory to understand cooperation



Humanity's shared resources

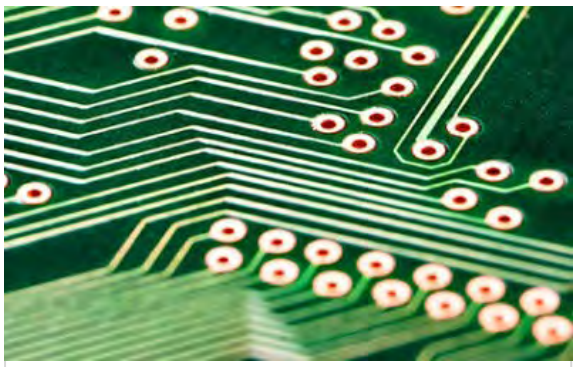
Education matters for all Sustainable Development Goals

Food security in a changing world

Sustainable use of water, energy, and land

Reaping the co-benefits of air pollution and climate policies

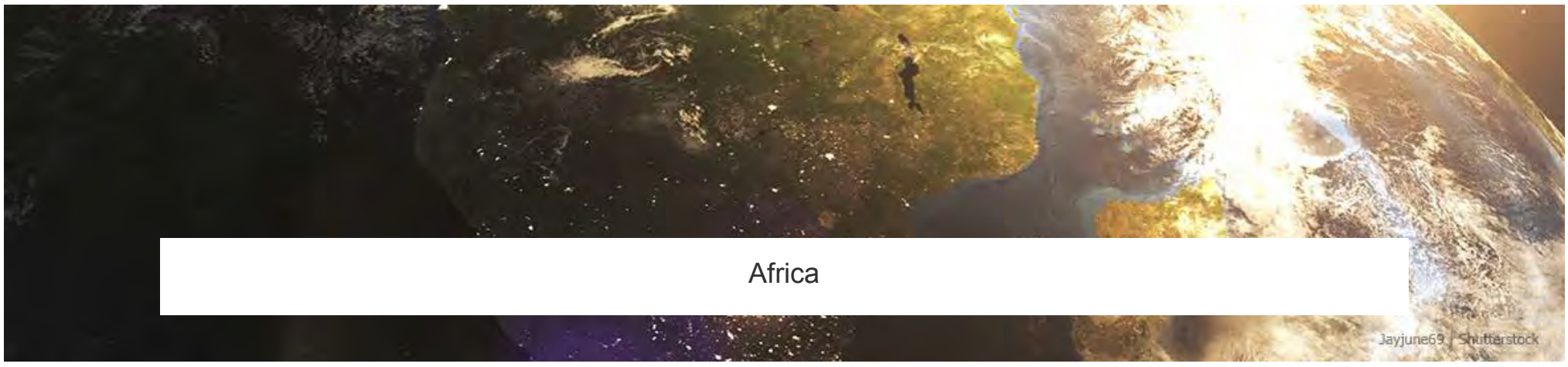
Shared Socioeconomic Pathways: Finding routes to sustainability



How to make fast transitions to sustainable pathways

Sustainable Development Goals lead to lower population growth

Negotiating climate loss and damage



Africa

The people of Africa are facing some of the worst consequences of climate change. IIASA research has included ways of improving climate resilience and food security in the region, as well as developing new tools to support policy decisions.

Selected highlights

Facing climate change in West Africa

Building security for farmers in Ethiopia

Smart policies for sustainability

Achieving sustainable agriculture

Sustainable use of water, energy, and land

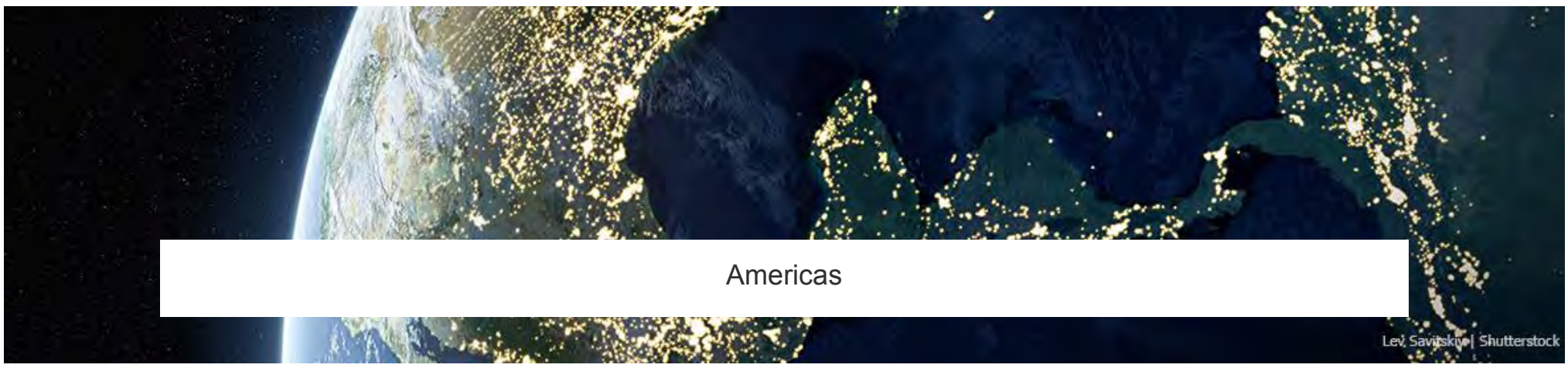
Guiding science and policy to robust climate action

Resilience of the global trade networks

Country factsheets

To learn more about IIASA connections and collaborations with member countries use the buttons on the right.

Egypt | South Africa



Americas

IIASA work across the Americas spans new approaches to disaster risk management; accounting for non-CO_2 greenhouse gases; and aging patterns, along with numerous other collaborations with institutes and researchers in the region.

Selected highlights

Guiding science and policy to robust climate action

Protecting fisheries from evolutionary change

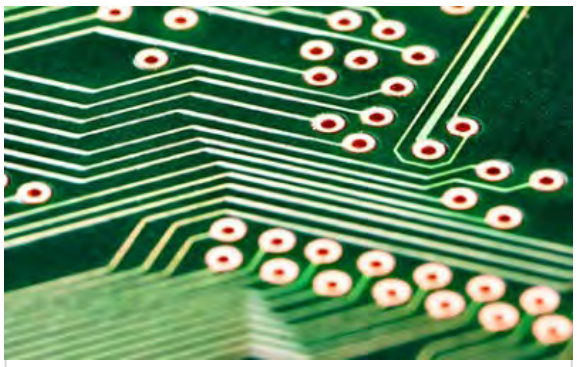
Improving efficiency to meet agricultural water demand

Getting the non-CO2 greenhouse gases right

Health, wellbeing, and aging in the Arctic

Food security in a changing world

Using game theory to understand cooperation



How to make fast transitions to sustainable pathways

Disaster forensics: Detecting best practice

Resilience of the global trade networks

Reducing water stress worldwide

Smart policies for sustainability

Energy and the Sustainable Development Goals

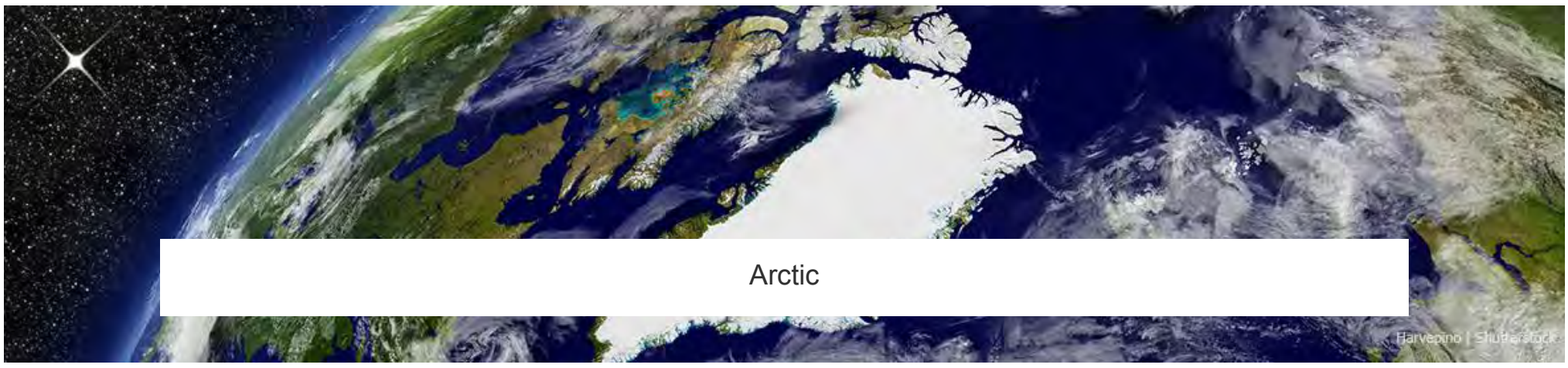
Exploring the new phenomenon of economic platforms

Sustainable transport through agent-based modeling

Country factsheets

To learn more about IIASA connections and collaborations with member countries use the buttons on the right.

Brazil | Mexico | USA



Arctic

The Arctic is a unique region facing a vast and rapid transformation. IIASA researchers have provided vital evidence on how communities and ecosystems in the region will be affected.

Selected highlights

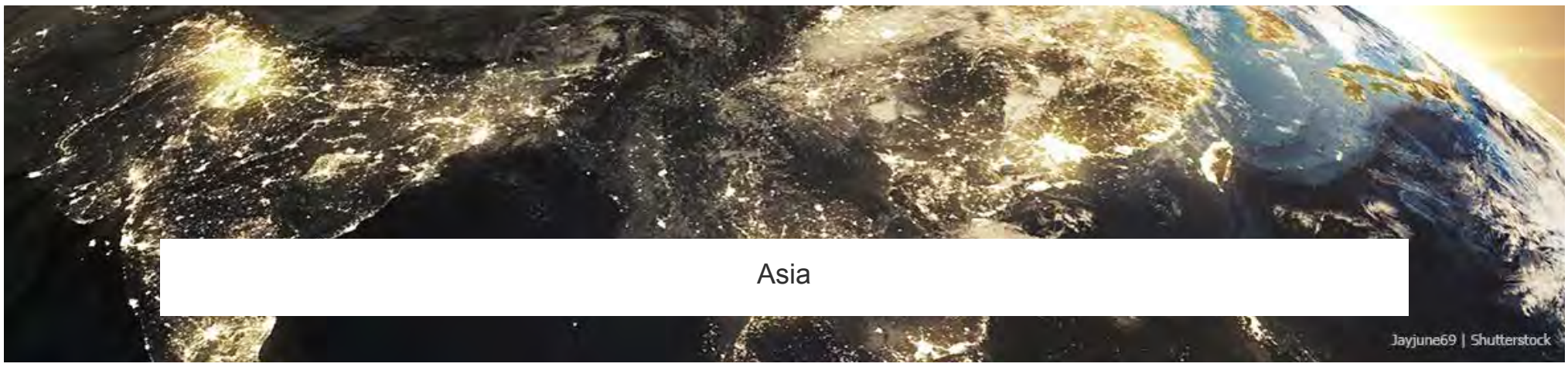
Loss and damage in the Arctic under climate change

Arctic resilience in a changing world

Sustainable fisheries management

Health, wellbeing, and aging in the Arctic

Protecting fisheries from evolutionary change



Asia

IIASA research has provided nations in Asia with the tools and evidence to improve energy access for the poorest, plan sustainable energy systems, and manage urban pollution.

Selected highlights

Think outside the city to manage urban pollution

Why do renewables grow faster in some countries than others?

Water security in Asia

Participatory mapping to enhance disaster resilience

Economic cooperation between the EU and Eurasian Economic Union

Counteracting disease spread over city commuter networks

Wildfires of the future

Energy and landscape sustainability in Indonesia

Smart policies for sustainability

Negative emissions in the tropics

Sustainable transport through agent-based modeling

Harnessing the power of citizen science

Reaping the co-benefits of air pollution and climate policies

Improving efficiency to meet agricultural water demand

Disaster forensics: Detecting best practice

Guiding science and policy to robust climate action

Sustainable Development Goals lead to lower population growth

Energy and the Sustainable Development Goals

Country factsheets

To learn more about IIASA connections and collaborations with member countries use the buttons below.

China | India | Indonesia | Iran | Japan | Korea | Malaysia | Pakistan | Vietnam

Europe

IIASA has actively assisted policymakers at both national and regional levels across Europe, including helping to shape the EU Renewable Energy Directive, creating comprehensive guidance on creating national nitrogen budgets, and providing a scientific basis to agricultural policy in Ukraine.

Selected highlights

Shaping European bioenergy policy

Labor market and migration across Eurasia

Informing European air quality policies

Tackling the nitrogen challenge

Who are the refugees?

Rethinking expert engagement in participatory processes

Loss and damage in the Arctic under climate change

Sustainable fisheries management

Exploring the new phenomenon of economic platforms

Robust land-use management

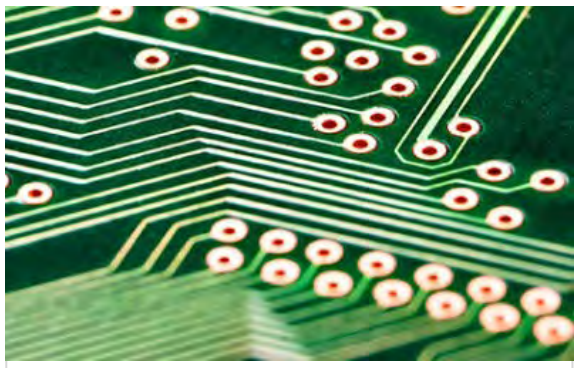
Harnessing the power of citizen science

Why do renewables grow faster in some countries than others?

Getting the non-CO2 greenhouse gases right

Guiding science and policy to robust climate action

Energy and the Sustainable Development Goals



How to make fast transitions to sustainable pathways

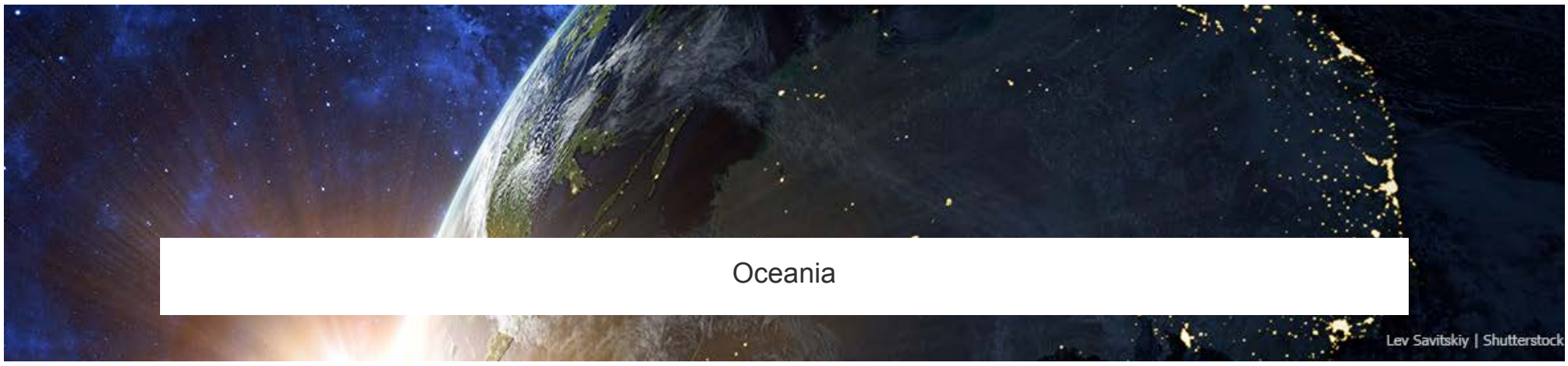
Protecting fisheries from evolutionary change

Can insurance effectively support climate resilience?

Country factsheets

To learn more about IIASA connections and collaborations with member countries use the buttons below.

Austria | Finland | Germany | Netherlands | Norway | Russia | Sweden | UK | Ukraine



Oceania

Collaborations with researchers and institutes in Oceania have been fruitful, yielding globally relevant work on issues from water security to climate action.

Selected highlights

Guiding science and policy to robust climate action

Reducing water stress worldwide

Water security in Asia

Loss and damage in the Arctic under climate change

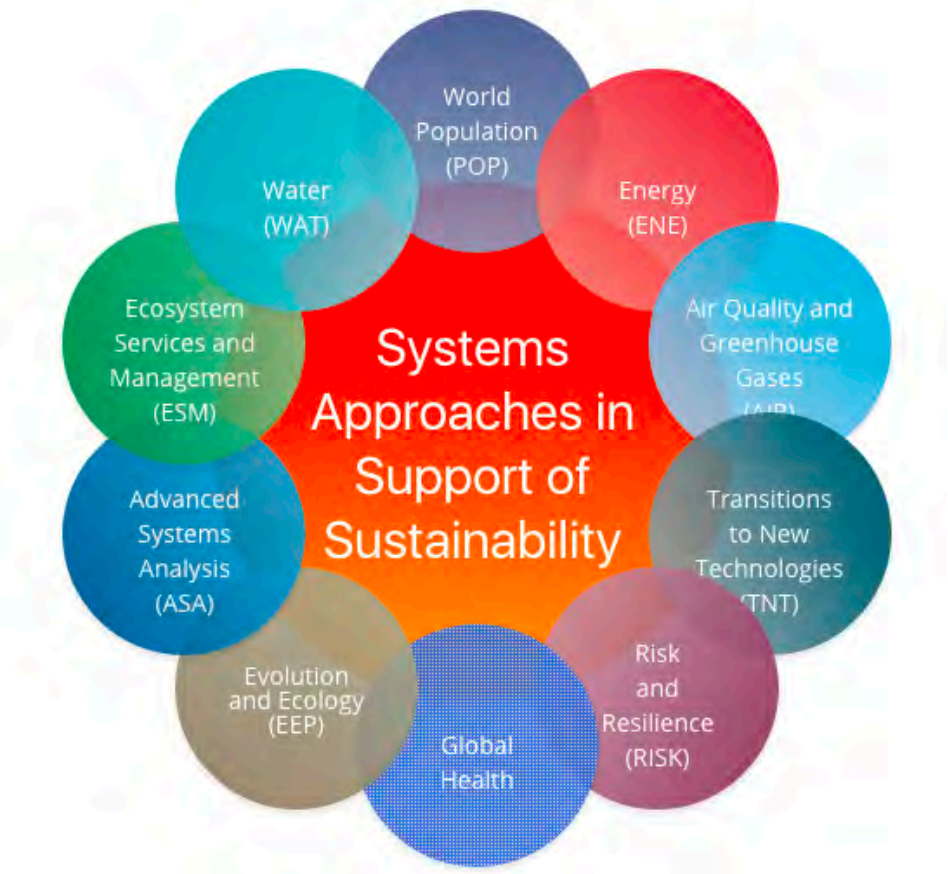
Country factsheets

To learn more about IIASA connections and collaborations with member countries use the button on the right.

Australia

Global, regional, national

IIASA by program



There are nine IIASA research programs carrying out research into the dynamics of global change. These programs use holistic approaches and effective, interdisciplinary collaborations to identify the multiple solutions needed to bring about a global transformation to true sustainability.

The IIASA research programs are shown in the interactive diagram. The outer circles show the current nine research programs and the proposed new Global Health Program. The inner circle represents integrated research activities at IIASA. Importantly, the diagram shows how each of the research programs intersect and contribute to these integrated projects, an increasing focus of IIASA research.

IIASA research programs are not discipline-based, but are themselves interdisciplinary and house a diversity of scientific expertise, across the natural, physical, and social sciences that together focus on a particular research theme.

Alongside this, the programs contribute to large-scale initiatives that span the institute, including the integrated and cross-cutting projects, futures initiatives, and the Systems Analysis Forum.


Future initiatives


Integrated projects


Cross-cutting projects


Systems Analysis Forum

Advanced Systems Analysis Program

Increasing recognition of the systems nature of global challenges, and unprecedented new streams of data from scientific, governmental, and commercial sources, require new and improved systems analysis approaches. Working in close cooperation with the applied researchers, the Advanced Systems Analysis Program works at the cutting edge of applied mathematics and modeling to expedite the transfer of application to methods and methods to application. In this way, the program develops more efficient solutions to problems or solves those that cannot be addressed by existing tools.

Program website
Scientific recognition
Publications
Staff
Events

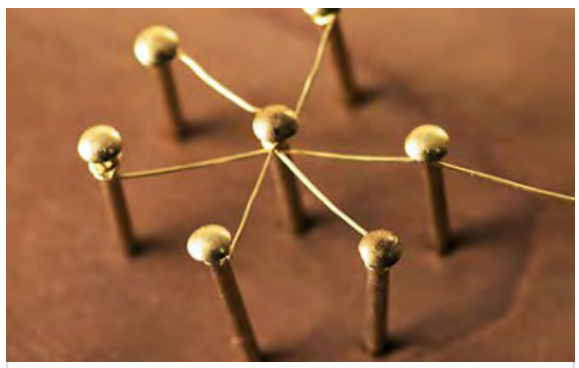
Objectives

- Enhance the program's scientific leadership at the interface between systems analysis methodology and applications, in particular, improve the methods and techniques used in decision-support models to deal with long-term non-linear dynamics, uncertainty, multiple agents, and multiple objectives.
- Improve the transfer of methods at IIASA by co-designing research questions and methods with stakeholders and policymakers, in particular, develop and implement new approaches to analyze the resilience of economic, financial, and ecological networked systems.
- Advance the approaches, practices, and rigor of qualitative research that involves stakeholders and decision makers, and enable the inclusion of the results into decision making.
- Showcase the utility of advanced systems analysis approaches and techniques in important, policy-relevant case studies. For example, advance economic growth and natural resource management models addressing sustainability.

Selected highlights

Sustainable consumption and economic growth

Using game theory to understand cooperation



Reducing the risk of financial crisis

Resilience of the global trade networks

Exploring the new phenomenon of economic platforms

Robust land-use management

Sustainable consumption and economic growth

Human exploitation of the Earth's resources is fast approaching planetary boundaries, and the closer we get, the greater the effects on human wellbeing. To aid the transition to a more sustainable path, the IIASA Advanced Systems Analysis Program is developing economic growth models, which inform green growth solutions.

New economic models, now urgently needed, must take into consideration inherent uncertainties and nonlinear effects that change over time. In the search for green growth solutions, IIASA researchers and collaborators have furthered the theory of optimal control for infinite-horizon problems, addressing classes of problems that are typical for economic applications, in which traditional methods fail to deliver rigorous solutions [1][2].

The researchers examined some classes of optimal control problems, which are subject to the Pontryagin maximum principle, working to generalize them over infinite time horizons with unbounded controls [1]. They were able to derive sufficient conditions for the existence of an optimal control, as well as conditions guaranteeing the uniform local boundedness of optimal controls in a general, nonlinear case. In a further study, the team derived the necessary first-order optimality conditions of Pontryagin's type for a general class of discrete-time optimal control problems on an infinite horizon.

To explore how renewable resources can be exploited sustainably, IIASA researchers considered a model of a logistically growing renewable resource. By applying the optimal control theory, they found that a consumption-based utility can increase or stay constant with the resource stock asymptotically non-vanishing only when the resource growth rate is higher than the difference between the discount factor and the technology growth rate adjusted to the elasticity of the production with respect to the resource [3].

To investigate the trade-off between consumption today and investment in the future, given the limited available natural resources, IIASA researchers used the Dasgupta-Heal-Solow-Stiglitz model. They showed that an optimal admissible policy may not exist if the output elasticity of the resource equals 1. In this case, an optimal solution does not exist for a sufficiently small initial stock of produced capital. This implies that it is impossible to formulate a welfare-maximizing policy at an early stage of economic development when produced capital is scarce and resources are abundant. An initial jump to the minimal stock of produced capital is therefore needed, followed by an optimal policy. The researchers characterized the optimal policies by applying a version of the Pontryagin maximum principle for infinite-horizon optimal control problems [4].

IIASA researchers also examined the effects of land ownership structures on population growth. Using a family-optimization model, where relative per capita wealth generates social status and wellbeing, they demonstrated that tenant farming is a major obstacle to escaping the Malthusian trap—a situation where technological advances that increase society's supply of resources do not lead to an increase in standards of living because the population simply grows faster in response. Land ownership reform provides farmers with higher returns for their investments, encouraging them to increase their productivity and status rather than their family size. Consequently, the population growth rate slows down, and the productivity of land increases [5].

Population growth can also be influenced by efforts to shift production away from polluting industries, a new study found. IIASA researchers modeled an economy where output is produced by two sectors, dirty and clean. An air pollution emissions tax curbs dirty production, which decreases pollution-induced mortality and shifts resources to the clean sector. If the dirty sector is more capital intensive (i.e., requiring a lot of physical capital—such as machines or other equipment—but not so much labor) the results show that this shift increases labor demand and wages. This, in turn, means that rearing a child is more costly because of the wages one would lose (known as the opportunity cost); this therefore decreases fertility and hence the population size. Correspondingly, if the clean sector is more capital intensive, then the emission tax decreases wages and increases fertility. Although the proportion of production from the dirty sector falls, the expansion of population boosts total pollution, aggravating environmental mortality [6].

Collaborators

- Steklov Institute of Mathematics, Russian Academy of Sciences, Russia
- University of Sofia, Bulgaria
- Technical University of Vienna, Austria
- Lahore University of Management Sciences, Pakistan
- Austrian Institute of Economic Research, Austria
- University of Helsinki, Finland

Advanced Systems Analysis Program

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Using game theory to understand cooperation

Cooperation is increasingly vital in this time of global change. IIASA researchers have been using game theory to investigate how to encourage individuals to cooperate and how to reduce as much as possible the negative impacts of non-cooperation.

Overfishing, greenhouse gas emissions, and air and water pollution: These are all examples of "tragedies of the commons," when individuals—acting according to their own self-interest—behave contrary to the best interests of the wider group by depleting or degrading a common resource. To determine how to avoid such tragedies, researchers from the IIASA Advanced Systems Analysis Program have been using a game-theoretic approach.

One of the major questions related to sustainability is how to convince people to modify their behavior in ways that reduce their consumption. A new IIASA study provides a unique new modeling framework, which translates findings from psychological research into a formula that can be applied to social and environmental perceptions and consumer behavior. The aim of this study was to see how much individual action can drive sustainable solutions, and how individuals influence each other.

The results showed that, at least in the theoretical framework, consumers' individual actions could go a long way towards optimizing the use of the shared resource. In particular, when individuals attached more relevance to information about the actions of others as compared to information about the state of the resource, they were more likely to modify their actions to reduce their own consumption.

Identifying ways to encourage individuals to cooperate remains a challenge. To tackle this, IIASA researchers developed a technique that allowed, for the first time, theoretical games to be decomposed into the portion that encourages individuals to seek personally preferred payoffs and the portion that requires cooperation among players [2].

An important form of cooperation is when society invests in protection against what are known as "contagious random attacks," such as an outbreak of a disease, a computer virus, or terrorism. Protection might therefore include vaccination programs or airport security. A recent IIASA study, using the mean-field approximation approach, shows that these different applications lead to very different equilibrium patterns of investments in protection, with important welfare and risk implications. For example, vaccination programs have a unique equilibrium in which more connected individuals are more likely to get vaccinated. However, airport security or certain types of computer security investments can lead to multiple equilibria and coordination failures [3].

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Advanced Systems Analysis Program

Collaborators

- Lahore University of Management Sciences, Pakistan
- University of California, Irvine, USA,
- European Institute of Business Administration

Reducing the risk of financial crisis

A financial crisis can start with the collapse of a single bank. As other institutions with financial links to the bank also get into trouble, a cascade of failures begins across the whole system, potentially leading to a global crisis. IIASA researchers have been working to reduce this "systemic risk."

Today, financial institutions around the world are becoming increasingly inter-dependent. As a result, the actions and interactions of individual organizations, even if small, can catalyze significant cascading effects, leaving the whole system susceptible to profound systemic risk.

As part of the cross-cutting IIASA project *Systemic Risk and Network Dynamics*, which also involves the institute's Evolution and Ecology and Risk and Resilience programs, researchers from the Advanced Systems Analysis Program have developed new approaches to modeling network dynamics and to assessing and managing systemic risk using agent-based modeling and game theory.

In recent work, IIASA researchers proposed a potential method—a "systemic risk tax"—to encourage the financial network to self-organize to reduce risk. This tax on individual transactions between financial institutions would be based on the level of systemic risk that each transaction adds to the system—and could essentially eliminate the risk of collapse of the financial system [1].

A further study on this topic used an equilibrium concept inspired by the matching markets literature, and showed that in addition to allowing a regulator to effectively "rewire" the interbank network so as to make it more resilient, a systemic risk tax also does so without sacrificing transaction volume [2].

An alternative way to mitigate systemic risk is to use credit default swaps. These are agreements where the seller will compensate the buyer in the event of a loan default by the third party debtor. Since these transfer the default risk from one bank to another, a market for credit default swaps can be designed to rewire the network of interbank exposures in a way that makes it more resilient to insolvency cascades. This works in a similar way to the systemic risk tax [1], by effectively taxing the credit default swaps based on the level of systemic risk that they add to the system. This makes the entire network more resilient to domino effects [3].

Reducing financial systemic risk is also the aim of the third Basel Accord—a global, voluntary regulatory framework on bank capital adequacy, stress testing, and market risk. However, the accord as planned will not reduce systemic risk in a substantial way, IIASA research, using an agent-based model, has found [4].

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Advanced Systems Analysis Program

Collaborators

- University of Oxford, UK

Resilience of the global trade networks

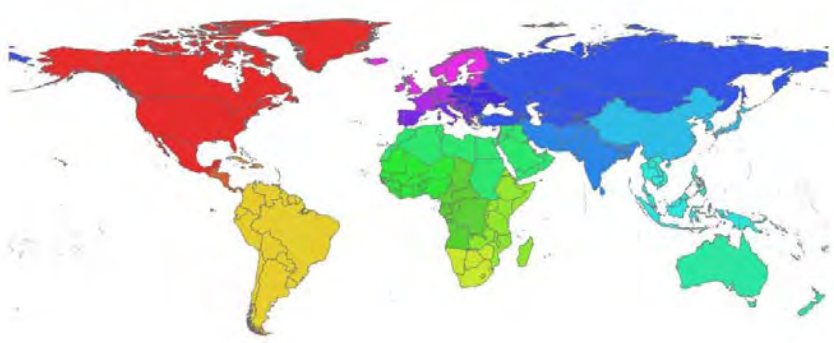
Today's supply chains extend across the world and trade is a truly global phenomenon. It is therefore an issue of national security for every country to ensure the sustainability of their exports and imports. To help tackle this, IIASA researchers have analyzed key trade networks related to food and energy security, and examined their resilience and function.

Seafood plays an important role in food security, making up nearly 20% of animal protein consumption around the world. At the same time, seafood supplies are vulnerable to natural disasters, fishery collapses, policy changes, and price spikes in fossil fuels.

To examine how seafood trade might be affected by such shocks, researchers from the IIASA Advanced Systems Analysis and Evolution and Ecology programs developed a shock-propagation global trade network model. The results show that Central and West Africa are the most vulnerable to shocks. In addition, if such an event did occur, richer regions might be more willing to prioritize their domestic consumption, which would pass on the shock to other regions in the trade network. If this is taken into account in the model, the researchers found, Central and West Africa are even more at risk.

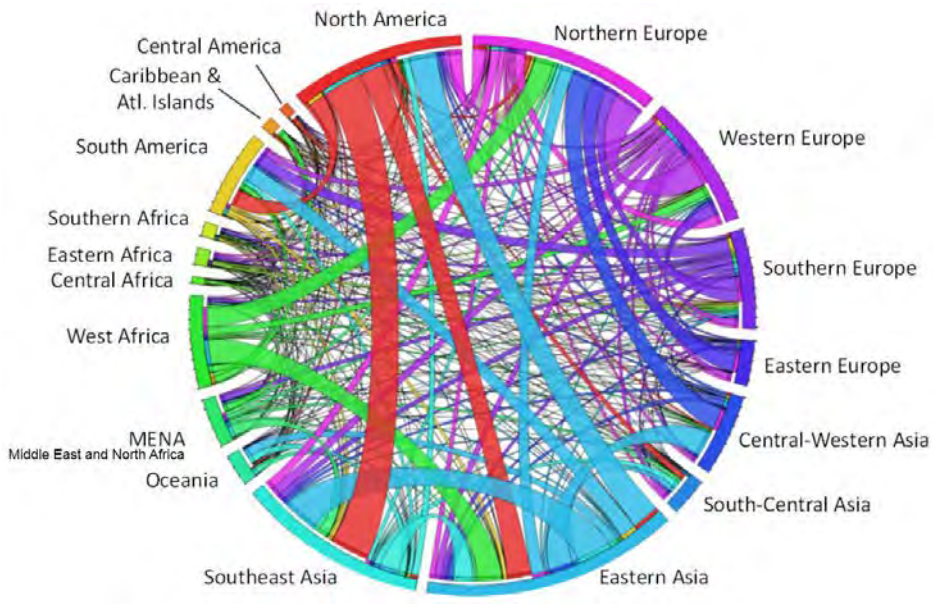
These findings suggest that countries can reduce their overall vulnerability to shocks by reducing reliance on imports and diversifying food sources. As international seafood trade grows, identifying these types of potential risks and vulnerabilities is important to build a more resilient food system [1].

Another important factor to take into account in trade networks is "non-market forces"—such as preferential trading agreements between countries that are not related to supply and demand. To reveal these non-market forces in trade networks, IIASA researchers developed a diagnostic tool and tested it on the oil trade—one of the most important networks in the global economy.



By analyzing the historical trends in oil trade, the researchers determined the pairwise trade preferences and dependencies using a point-wise mutual information method. This approach compares the actual reality of the trade network with a 'neutral' model, in which bilateral trade is purely determined by each country's supply and demand constraints.

For example, using the tool, the team demonstrated that actual amount of oil imported from Canada to USA was seven times larger than suggested by the demand-supply based neutral model. This can be attributed to the non-market impacts of geographical proximity and some preferentiality [2].



Global seafood trade among world regions. A band's width represents the traded biomass and a band's color represents the importing region. The new study assesses the vulnerability of world regions to supply shocks in this trade network.

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Advanced Systems Analysis Program

Collaborators

- University of Virginia, USA

Exploring the new phenomenon of economic platforms

Businesses that provide "platforms"—such as an app store for mobile phones—allow other companies to build on them, and connect to a network of consumers. This powerful structure is still an emerging phenomenon but has the potential to transform economies. The Platform Value Now project brings together researchers and national policy advisors in Finland to jointly develop a policy to support such businesses as a key part of the nation's economy.

A platform is a foundation on which others can stand, and the same is true in economics. If you build a digital platform, for instance, other businesses can easily connect their business with yours and build products and services on top of it. Take Apple or Android, their real success is not from features or functions, it is from the app store which allows external developers to create value. The *Platform Value Now* project, funded by the Finnish Strategic Research Council, focuses on understanding these emerging platform structures and how they could work in the Finnish economy.

The typical features of the current platform companies are: a global nature, extremely fast growth, and lots of interest from investors. Companies such as Amazon, Airbnb, and Uber are operating globally and collecting a large share of the value generated.

Currently, 80% of platform businesses are American and 80% of these are located in California. The recent developments indicate that those companies that are fast to join existing platforms or initiate platforms themselves are starting to dominate, making it difficult for others to get into the market. For a policymaker in Finland, or anywhere outside the USA, the challenge is that the value staying in the country is currently small, and it therefore does not support local employment.

The potential impact on public funding is even more serious, because a large amount of the taxable income is transferred to another country. To assess the impact of this, IIASA researchers have developed methods to measure the un-captured GDP, that is, the share that is lost to platform companies operating from other countries [1][2].

As part of the project, IIASA researchers have analyzed platform policies in different countries and alternative government roles and options. These were part of a special report on global scenarios and alternative pathways of platform economy development, which contributed to the prime minister's strategic development project: *the Road Map of the Finnish Platform Economy*, to be published in 2017.

The project continues to collaborate closely with the team of senior civil servants that are responsible for platform economy development in the Corporate Steering Unit of the Finnish Ministry of Employment and the Economy.

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Advanced Systems Analysis Program

Collaborators

- Aalto University, Finland
- Stevens Institute of Technology, USA
- University of Jyvaskyla, Finland

Robust land-use management

Providing policymakers with robust guidance on land-use management is becoming increasingly difficult under the uncertainties of climate change. IIASA researchers have now updated the institute's large-scale land-use model to better incorporate these uncertainties, and used it to provide the Ukrainian government recommendations for sustainable management of agriculture.

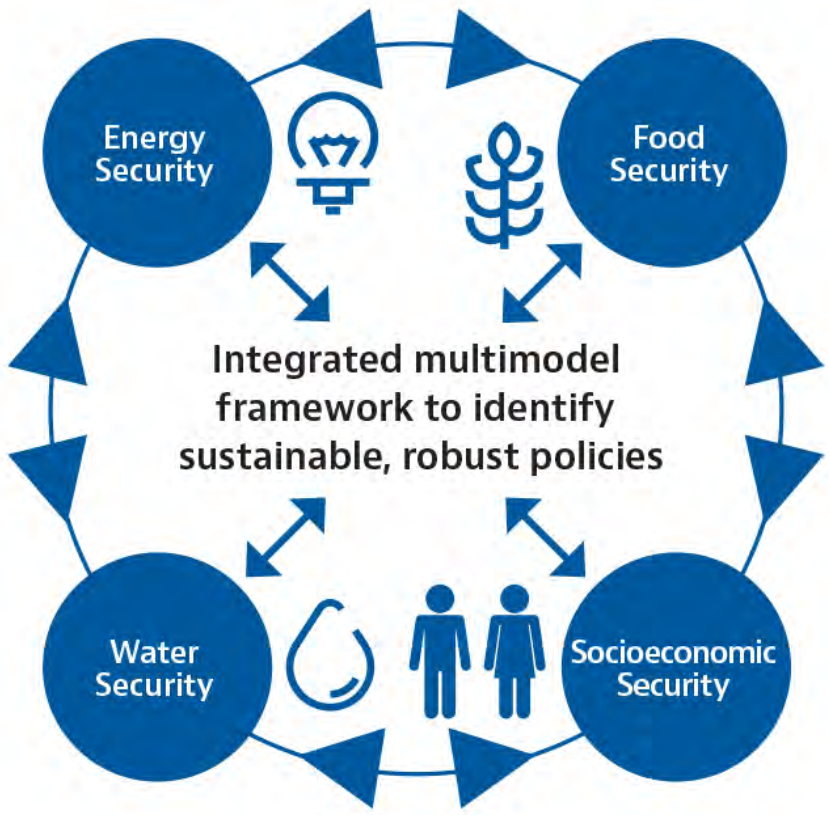
The IIASA Global Biosphere Management Model (GLOBIOM) is used to analyze the competition for land between agriculture, forestry, and bioenergy. While it was originally developed as a global model, GLOBIOM can be adjusted to analyze strategies for sustainable development on national scales as well.

Agriculture currently generates about 10% of Ukrainian GDP and national food security largely relies on small, often family-owned farms, which meet domestic demand for major crops despite the fact that they are neither efficient nor profitable. At the same time, large agri-businesses produce more profitable crops and take advantage of the economy of scale, exporting most of their produced food abroad.

To help policymakers tackle these and other problems, researchers from the Advanced Systems Analysis Program in collaboration with the Ecosystems Services and Management program, working as part of the project *Integrated Modeling of Robust Solutions for Food, Energy, and Water Security Management*, have down-scaled GLOBIOM to apply it to Ukraine [1]. This can provide detailed, national-level advice that is consistent with global targets, and IIASA work has now been used as input for Ukraine's Strategy of Agriculture and Rural Development, prepared with the support of the UN Food and Agriculture Organization.

Recommendations for policymakers must be robust in the face of uncertainties: a policy that only works in an entirely predictable world is useless.

To ensure that GLOBIOM provides guidance that is robust under all eventualities, IIASA researchers developed a stochastic version of the model that incorporates uncertainties and risks related to weather variability and climate change. The team has also improved the way GLOBIOM models the vulnerability of global supply chains to shocks such as natural disasters or price spikes, by including risks of low-probability, high-impact events. Their analysis showed clear benefits of the stochastic technique over the commonly used deterministic approach [2].



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Advanced Systems Analysis Program

Collaborators

- National Academy of Sciences, Ukraine

Further information

IIASA impact sheet: Robust food, energy, water, and land management

Air Quality and Greenhouse Gases Program

The IIASA systems approach to air quality and greenhouse gas management is a unique example of a successful science-policy interface shaping global, regional, and national policies. Pioneering, interdisciplinary research into the interplay between rural and urban air pollution will provide the badly needed evidence to support measures that deliver local and near-term benefits while also contributing to global and long-term policy targets.

Program website
Scientific recognition
Publications
Staff
Events

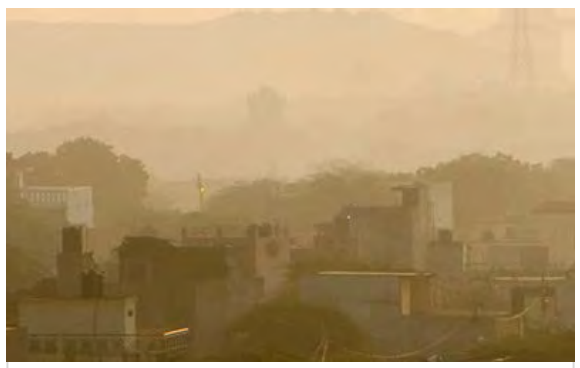
Objectives

- Develop an integrated approach relevant for urban policymakers in industrialized and developing countries, with intuitive user-interfaces for decision makers and stakeholders not trained in systemic air quality management.
- Quantify the interplay between urban and rural air pollution, considering the physical exchange of pollution in the atmosphere, diversity in emission sources, health impacts, and social factors.
- Analyze the drivers and sources of air pollution and their impacts on design policy interventions that deliver benefits to different social groups and economic sectors.
- Establish a new urban management tool for practical policy analyses in a variety of cities in industrialized and developing countries.
- Connect the new urban analysis tool with the global Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) tool to explore the regional and global effects of urban decisions.
- Quantify the contributions of specific policy interventions in achieving the UN Sustainable Development Goals.

Selected highlights

Getting the non-CO2 greenhouse gases right

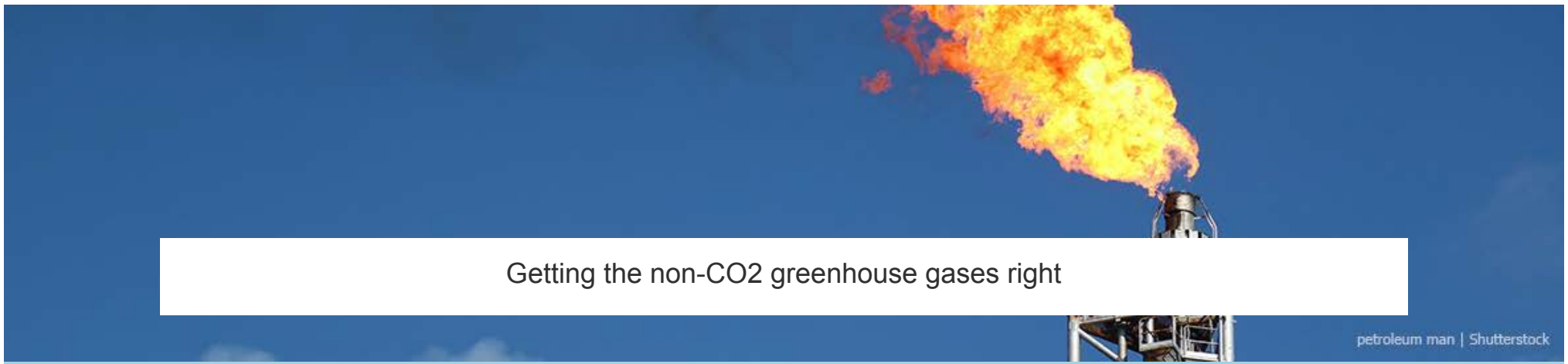
Reaping the co-benefits of air pollution and climate policies



Think outside the city to manage urban pollution

Tackling the nitrogen challenge

Informing European air quality policies


petroleum man | Shutterstock

Getting the non-CO2 greenhouse gases right

There are many important greenhouse gases besides CO_2: in fact they account for about 20% of total greenhouse gas emissions in the EU. The IIASA Air Quality and Greenhouse Gases Program has developed new methods to investigate the three most important—methane, fluorinated gases, and nitrous oxide—determining how much is released, how to reduce their emissions, and what the costs of this will be.

Gas flares are used in oil production to burn off waste gas but occasionally they fail to burn, releasing methane—a greenhouse gas about 30 times more potent than CO_2. These releases have long been underestimated in national emission inventories because no one has attempted to systematically monitor the volumes of gas that escape during this 'cold venting.'

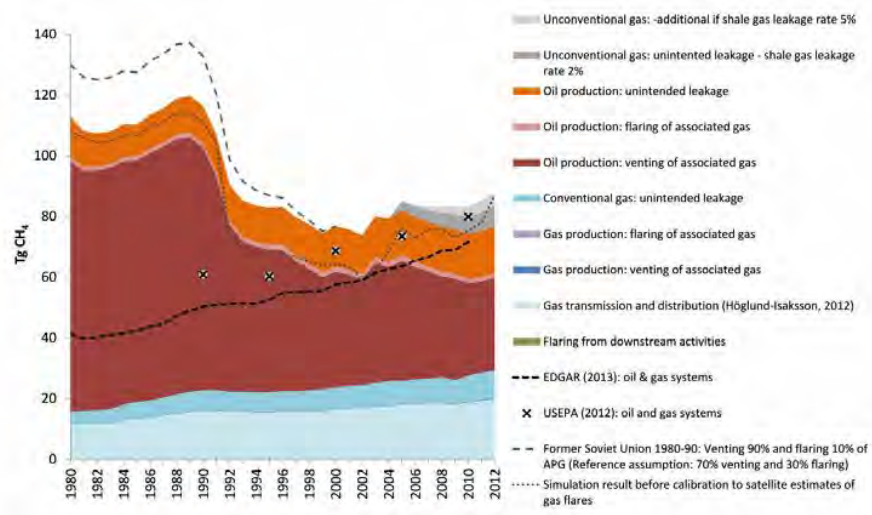
To address this, an IIASA study brought together all available information on the handling of gases released through oil production for around a hundred countries. The team used this to derive global estimates of the volumes of gas flared and vented that are consistent both with country-specific flaring volumes estimated from satellite images, and total generation and recovery of gas taken from energy statistics. Only in Canada have direct measurements of venting been taken, and these patterns were therefore used for all countries. The results demonstrated that methane emissions where much higher than previously estimated [1].

The study also examined ethane, which is a better tracker for these emissions than methane, because it does not last long in the atmosphere, and oil and gas production is its dominant source. Ethane emissions estimated using the improved method correspond remarkably well to top-down atmospheric measurements, explaining much of the existing divergence between bottom-up and top-down estimates [2].

Global oil and gas systems are estimated to have released about 3 metric gigatons of methane over the study period 1980-2012, which will cause the same amount of global warming as about 100 billion metric tons of CO_2 over 100 years. For the earlier years, this means more than double the corresponding methane emissions estimated by the US Environmental Protection Agency and Electronic Data Gathering, Analysis and Retrieval databases.

Fluorinated gases, commonly used as cooling agents in refrigerators and air conditioners, also have a strong greenhouse effect. They have come under increasingly stringent regulations, including the Kigali Agreement, which was signed by 170 countries in 2016. To estimate the current and future releases of fluorinated gases under the new rules, IIASA researchers developed a tool in the Greenhouse Gas – Air Pollution Interactions and Synergies model.

The tool can also be used to estimate the costs for complying with the agreement from 2016 to the phase-out of these gases in 2050 [3].



Methane emissions from global oil and gas systems when using new estimation methodology and in comparison to existing bottom-up inventories from US Environmental Protection Agency and Electronic Data Gathering, Analysis and Retrieval.

The third most important greenhouse gas is nitrous oxide, but it is often ignored in climate mitigation measures. Its main anthropogenic source is agriculture, and by analyzing global emissions of the gas from atmospheric concentration measurements, IIASA researchers concluded that under standard agricultural practice biofuel production will typically cause more greenhouse gas emissions in the form of nitrous oxide than it will save on fossil fuel CO_2 emissions [4]. Although they are not adequately enforced, laws for the regulation of this potent greenhouse gas do exist. For instance, IIASA research found that the US Clean Air Act provides considerable authority to reduce national nitrous oxide emissions, even though it was designed to address its ozone depleting, rather than global warming, properties [5].

Air Quality and Greenhouse Gases Program

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Reaping the co-benefits of air pollution and climate policies

For more than a decade, the IIASA Air Quality and Greenhouse Gases Program (AIR) has pioneered the analysis of the co-benefits of climate policies on local air quality and human health. Continuing this work in 2016, the program has fostered close collaborations with the energy research community, demonstrating that many solutions to reducing emissions and improving health lie within the energy sector.

Air quality and climate policies can provide substantial mutual benefits: climate change mitigation actions can help reduce air pollution, and clean air measures can help reduce greenhouse gas emissions.

In 2016, a collaborative project using the Integrated Model to Assess the Global Environment confirmed that, because of the overlap between greenhouse gas and air pollutant emission sources, climate mitigation policies have the highest impact on emissions of sulfur dioxide and nitrogen oxides, while their impact on black carbon (soot) and organic carbon emissions is relatively low. At the global scale, climate policy can have important co-benefits; a 10% decrease in global CO_2 emissions by 2100 leads to a decrease of emissions of sulfur dioxide and nitrogen oxides by about 10% and 5% respectively, compared to 2005 levels [1].

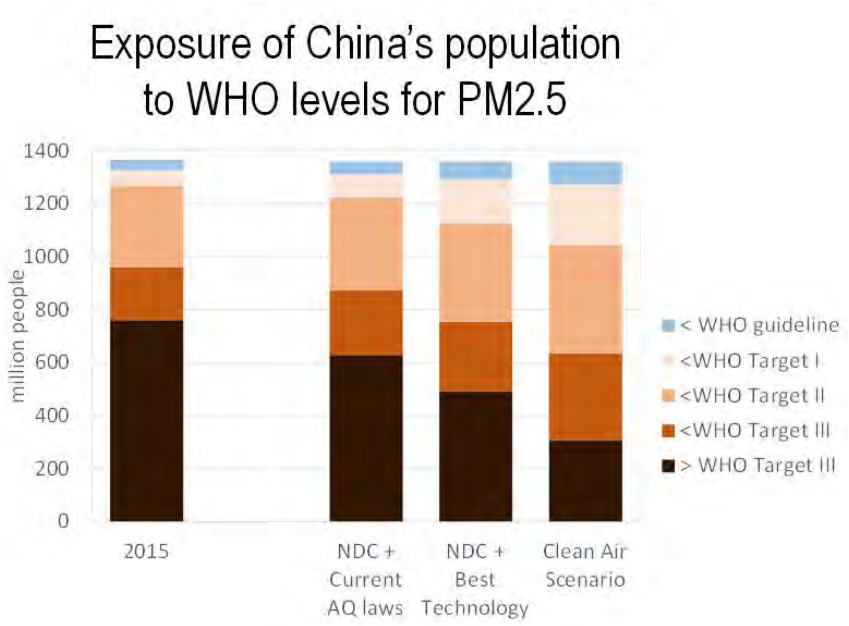
Energy production is, of course, central to both climate change and air pollution issues, and AIR has recently been working with the institute's Energy Program, as well as a number of external energy modeling groups. The researchers explored various pollution control policies, complemented by climate mitigation policies that foster technology and fuel transformations in energy systems.

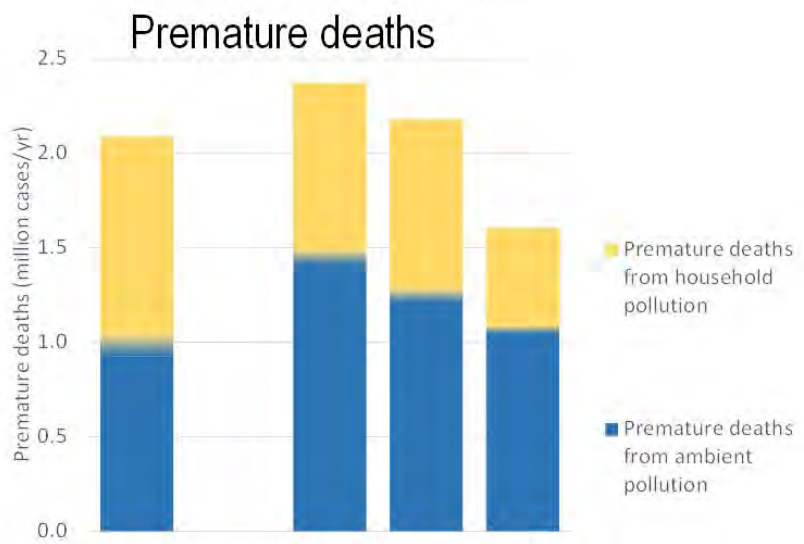
The results showed that a combination of stringent air pollution policies and climate change mitigation could provide clean air to about 60% of the world's population, with the largest improvements in India, China, and the Middle East. The study reinforces the importance of integrated policies that address multiple sectors in achieving the UN Sustainable Development Goals [2].

The critical role of policy decisions in the energy sector to securing clean air was also the topic of a study undertaken with the International Energy Agency [3]. Many solutions to reducing emissions and improving health and living conditions lie within the energy sector, the study confirmed. However, aging and urbanization will counteract the health benefits of policy measures, and even tighter measures will be needed if the aim is to reduce the total health burden in future.

While recognizing that non-energy related sources make substantial contributions to air pollution, especially in developing Asia, the study demonstrated that a comprehensive 'Clean Air' approach, building on proven measures and policies, offers a cost-effective way for the energy sector to reduce health impacts from air pollution.

Air Quality and Greenhouse Gases Program





Although effective implementation of air pollution control strategies will reduce population exposure to harmful pollution (upper panel), the actual health benefits will be counteracted by the aging of societies, because the elderly are more sensitive to air pollution. Source: IEA 2016

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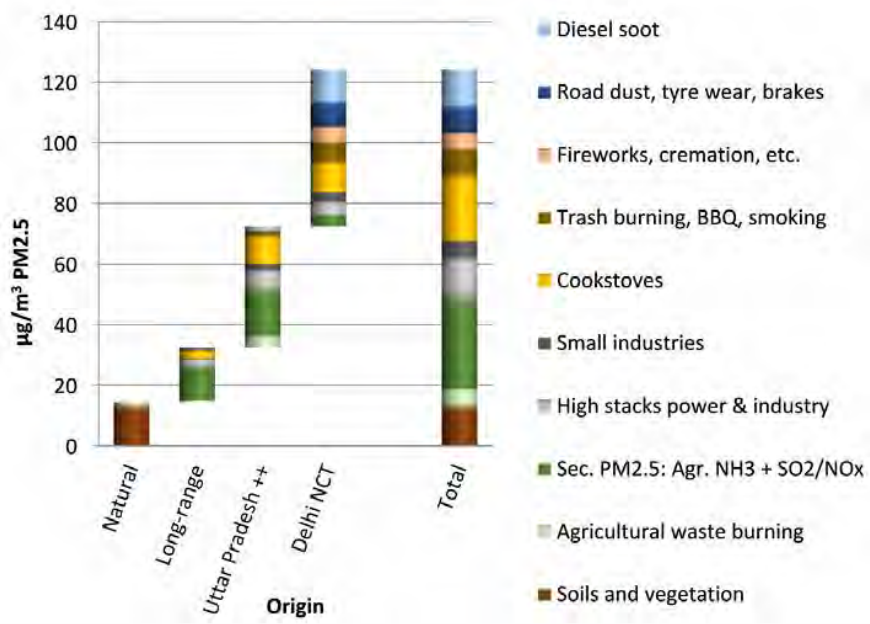
Collaborators

- Netherlands National Institute for Public Health and the Environment (RIVM) Integrated Model to Assess the Global Environment group (Detlef van Vuuren)
- Joint Research Centre for the European Commission, Ispra, Italy (Frank Dentener)
- International Energy Agency

Think outside the city to manage urban pollution

Only around 40% of the fine particulate matter pollution in Delhi originates from within the city, and about 60% percent is transported from outside, an IIASA study found. This illustrates the problem with focusing on urban areas when looking for solutions to air pollution. To address this, the IIASA Air Quality and Greenhouse Gases Program (AIR) has developed a blue-print for managing air pollution in fast-growing megacities in developing countries, showing that effective solutions require regional and multi-sectoral cooperation.

As most people live in cities, air pollution is widely considered an urban problem, and traditionally solutions are sought at the urban level. However, air pollution can travel over long distances, and conventional solutions that deal with air pollution on a local level, such as policy responses by city administrations, cannot deliver effective solutions.



Contributions from different sources to population exposure to PM2.5 in Delhi, 2015. Uttar Pradesh is an Indian state that borders Delhi NCT (the National Capital Territory of Delhi).

In a joint project with the Indian Institute for Environmental Engineering Research, AIR used its Delhi -specific Greenhouse Gas – Air Pollution Interactions and Synergies model (GAINS-Delhi) to explore management options that could efficiently improve air quality in the city, with a focus on fine particulate matter pollution ($PM_{2.5}$). The work also provides a blue-print for managing air pollution in other fast-growing megacities in developing countries.

Despite the large size of Delhi, currently about 18 million inhabitants, only around 40% of the $PM_{2.5}$ the population is exposed to originates from local emissions, about 60% percent is transported into the city from outside, the study found. Contrary to widespread belief, traffic contributes only about 15-20% of the $PM_{2.5}$ the population is exposed to. In fact, the majority originates from a combination of other sources, including households, small-scale industries and workshops, trash burning, agriculture, and fireworks.

Recent regulations to control emissions from large individual sources in the surrounding areas should stabilize the pollution coming into the city, the researchers found. However, the decline in particulate matter in exhaust gas as a result of new traffic standards in Delhi is likely to be negated by non-exhaust emissions—such as road dust, and tire and brake wear—that will increase along with the expected growth in traffic volumes. The anticipated economic growth is also likely to counteract the benefits of the ambitious pollution control measures adopted by the authorities. As a consequence, the researchers conclude, air quality will continue to deteriorate.

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Air Quality and Greenhouse Gases Program

Collaborators

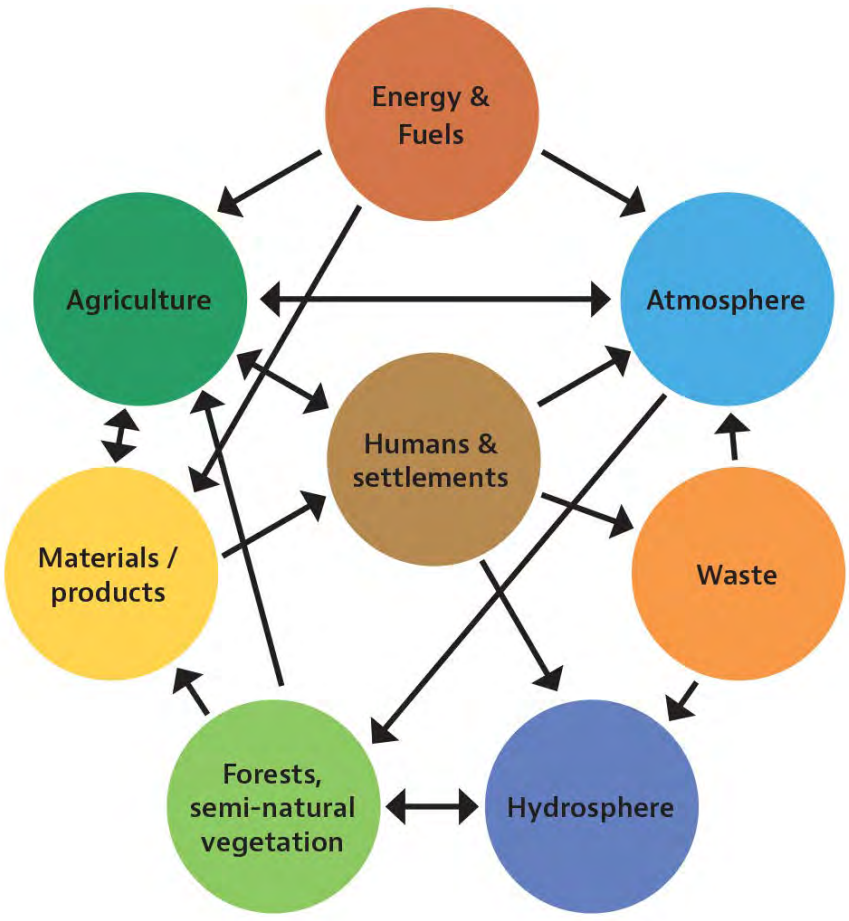
- Indian Institute for Environmental Engineering Research

Tackling the nitrogen challenge

Minimizing the environmental damage caused by nitrogen fertilizer while maximizing food production is known as the "nitrogen challenge." To help countries face this challenge, IIASA researchers have developed consistent, comprehensive guidance on creating national nitrogen budgets. Based on a systems approach, the guidance helps avoid trade-offs and allows countries to compare performances and share best practices.

While nitrogen compounds are a crucial part of growing our food, they are also responsible for severe environmental consequences, from air and water pollution, to global warming and biodiversity decline. Human activities have had significant impacts on the global nitrogen cycle, and we have already exceeded the "planetary boundary" for nitrogen—a tipping point that brings the risk of irreversible and abrupt environmental change.

The IIASA Air Quality and Greenhouse Gases Program has taken a systems approach to the "nitrogen challenge," quantifying nitrogen flow and identifying possible interventions to reduce environmental impacts while retaining agricultural productivity.



The concept of environmental stocks (circles) and major flows (arrows) of nitrogen compounds used for the National Nitrogen Budgets Guidance Document.

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Collaborators

- Centre for Ecology and Hydrology, Natural Environment Research Council, UK
- Umweltbundesamt, Germany

Researchers from the program led an international team to develop the National Nitrogen Budgets Guidance Document—specific guidance for European countries on how to use their available data for nitrogen budgets.

The approach could form the foundation of an International Nitrogen Management System, applied to countries around the world. At the same time, researchers are also working to extend the concept to individual farms, to give local, small-scale coverage.

The researchers used a framework made up of stocks and flows, which accounts for all nitrogen as it moves though the entire system. This approach minimizes the chances of unforeseen trade-offs; a solution drawing nitrogen out of the air, for example, is no good if it ends up polluting the rivers.

Using the generic rules of the guidance document and nitrogen data specific to their country, national experts can create accurate nitrogen budgets and assess flows. Comparing flow estimates allows users to validate information, and supplement missing data. For instance, if you know how much nitrogen fertilizer went on to the field and how much stayed in the soil and was taken up by plants, then you can deduce how much was lost to the rivers.

The approach allows countries to compare performances and share best practices, and forms the backbone of intervention planning to reduce nitrogen pollution across the system.

IIASA researchers have used the approach to examine nitrogen flows in non-food industrial products (polymers, wood and paper products, waste), and nitrogen related to pets, gardens, and energy use [1]. The team has also used the framework to assess the costs of measures aimed at reducing nitrogen emissions from livestock production via new feeding strategies [2].

The guidance document is fully compatible with existing reporting guidelines, specifically regarding countries' obligations to the UN Framework Convention on Climate Change, the UN Economic Commission for Europe (UNECE), and Eurostat. It has also been adopted by the UNECE Convention on Long Range Transboundary Air Pollution, and was specifically referred to in a 2016 EU Directive on atmospheric pollutants.

The approach could form the foundation of an International Nitrogen Management System, applied to countries around the world. At the same time, researchers are also working to extend the concept to individual farms, to give local, small-scale coverage.

Air Quality and Greenhouse Gases Program

Informing European air quality policies

The Air Quality and Greenhouse Gases Program has provided the quantitative analysis for EU air quality policies since 1995, including the National Emissions Ceiling Directives, the Gothenburg Protocol revisions, and the Thematic Strategy on Air Pollution. In 2016, the EU reached a landmark agreement based on analyses using the program's Greenhouse Gas – Air Pollution Interactions and Synergies (GAINS) model, which will cut the health impacts of air pollution in half.

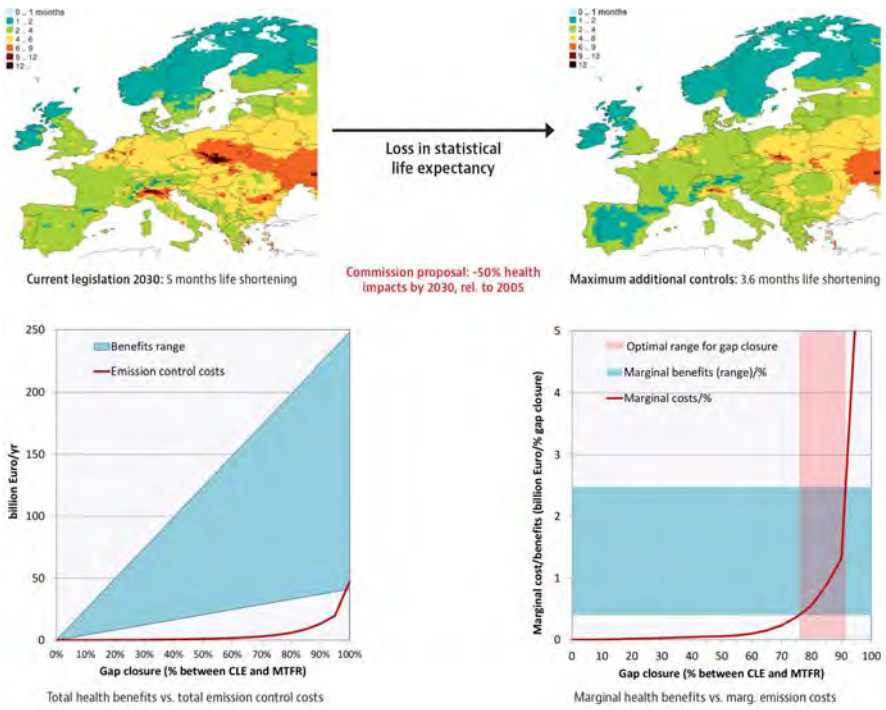
Extensive GAINS analyses of the costs and benefits of additional air pollution control measures and their impacts across EU member states and economic sectors formed the basis of the European Commission's "Clean Air Policy Package." This was a proposal for air quality legislation that would cut the health impacts of air pollution in the EU in half by 2030, compared to 2005, as well as reducing environmental impacts such as forest damage and biodiversity loss.

First presented by the Commission in 2013, the proposal was then discussed by the European Parliament and the European Council. While the political positions of the three institutions differed, for the first time ever they all agreed on the use of a common scientific tool: the IIASA GAINS model, as a shared knowledge base that feeds latest scientific findings into actual policy negotiations. To foster the acceptance of GAINS as a shared tool, the Air Quality and Greenhouse Gases Program hosted bilateral consultations with more than 100 experts of all 28 EU member states to review and improve the GAINS databases and align them with national information.

On request by the European Commission and the European Council, the program also produced a series of 17 policy reports that address critical issues on the potential and costs of further emission control measures (e.g., for transport, agriculture, and small combustion sources), and explore the implications of Europe-wide cost-effective strategies for reducing health impacts in the various member states and economic sectors. The reports also explain the GAINS methodology and input data.

In 2014, the European Parliament requested a specific study from IIASA to outline the impacts of the recently agreed climate policy targets on implementation costs of the proposed national emission ceilings for air pollution. In addition, the study explored economically rational adjustments of the ambition levels for air quality policies [1].

After extensive policy negotiations, in 2016 the three European institutions agreed on a compromise solution that establishes the upper limits for emissions of sulfur dioxide, nitrogen oxides, ammonia, volatile organic compounds, and fine particulate matter for each member state by 2030. This unprecedented agreement should reduce the health impacts from air pollution by 50% compared to 2005.



Total and marginal costs and benefits of further emission controls in the EU. The GAINS methodology identifies cost-effective portfolios of specific measures that improve local air quality and, at the same time, reduce global climate change. This approach, which focuses on actions that yield co-benefits at different spatial and temporal scales, provides a fresh perspective to clean air and climate policy development in many countries and world regions.

IIASA by program

Air Quality and Greenhouse Gases Program

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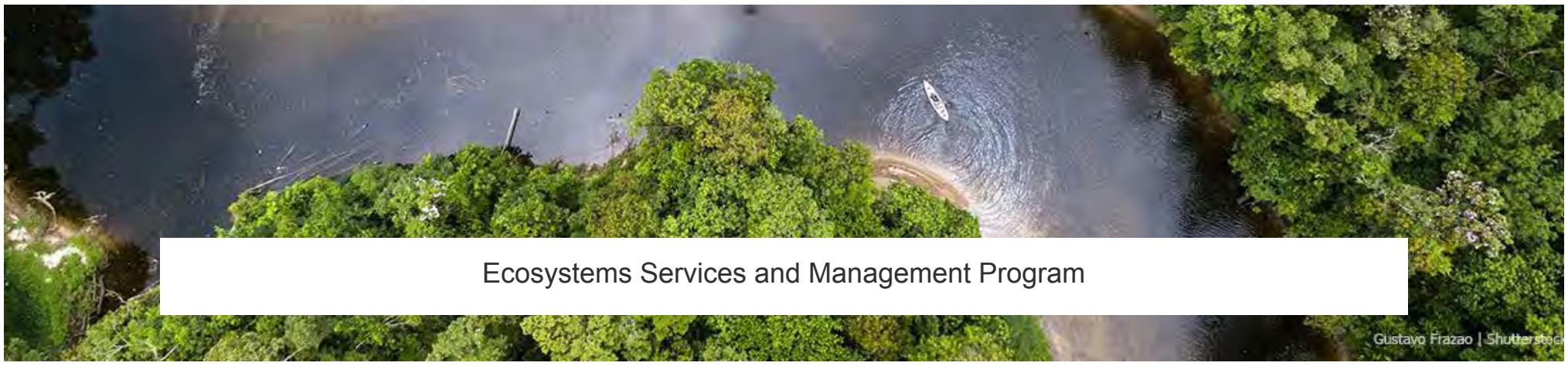
Further information

EU Clean Air Policy Package

Collaborators

In the process of policy development, AIR cooperated with a wide network of national scientific institutions and researchers, many of them IIASA alumni, to jointly elaborate the methodologies and databases of the GAINS model. Key contributions were made from research organizations from IIASA member countries, including:

- National Institute for Public Health and the Environment, Netherlands
- IVL Swedish Environmental Research Institute, Sweden
- Norwegian Meteorological Institute (MET.NO), Norway
- Finnish Environment Institute (SYKE), Finland
- Centre for Ecology and Hydrology, UK
- Imperial College, UK
- European Commission Joint Research Centres, Italy and Spain



Ecosystems Services and Management Program

The Ecosystem Services and Management Program has built integrated knowledge and data systems to provide a trusted science base for land management policy around the world. Guiding sustainable production and consumption choices that are consistent across scales and compatible with maintaining equitable access to ecosystem services is a scientific challenge that the program is uniquely positioned to address with its cluster of citizen science and modularly linked land resources assessment tools.

Program website
Scientific recognition
Publications
Staff
Events

Objectives

- Help develop global policy aimed at achieving the UN Sustainable Development Goals by focusing on integrated multiple natural resource use strategies and monitoring systems.
- Undertake at least three globally consistent national or regional policy impact assessments relevant to the three Rio Conventions on Biodiversity, Climate Change and Desertification.
- Launch an annual review of global resources and the commodity market by 2020, with consortium members recruited from IIASA member countries. Create a global natural resources market assessment network or consortium.
- Establish an open-access online platform for the market assessment consortium by 2020. The outlook will start with agriculture and forest sector commodities and eventually be expanded to minerals and metals markets.
- Establish a global citizen science center to initiate, host, and coordinate citizen initiatives aimed at crowd sourcing scientific data (inbound) and bringing research outputs to a wide audience (outbound).

Selected highlights

Food security in a changing world

Harnessing the power of citizen science

Building security for farmers in Ethiopia

Facing climate change in West Africa

Shaping European bioenergy policy

Using carbon markets to tackle climate change and protect forests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Food security in a changing world

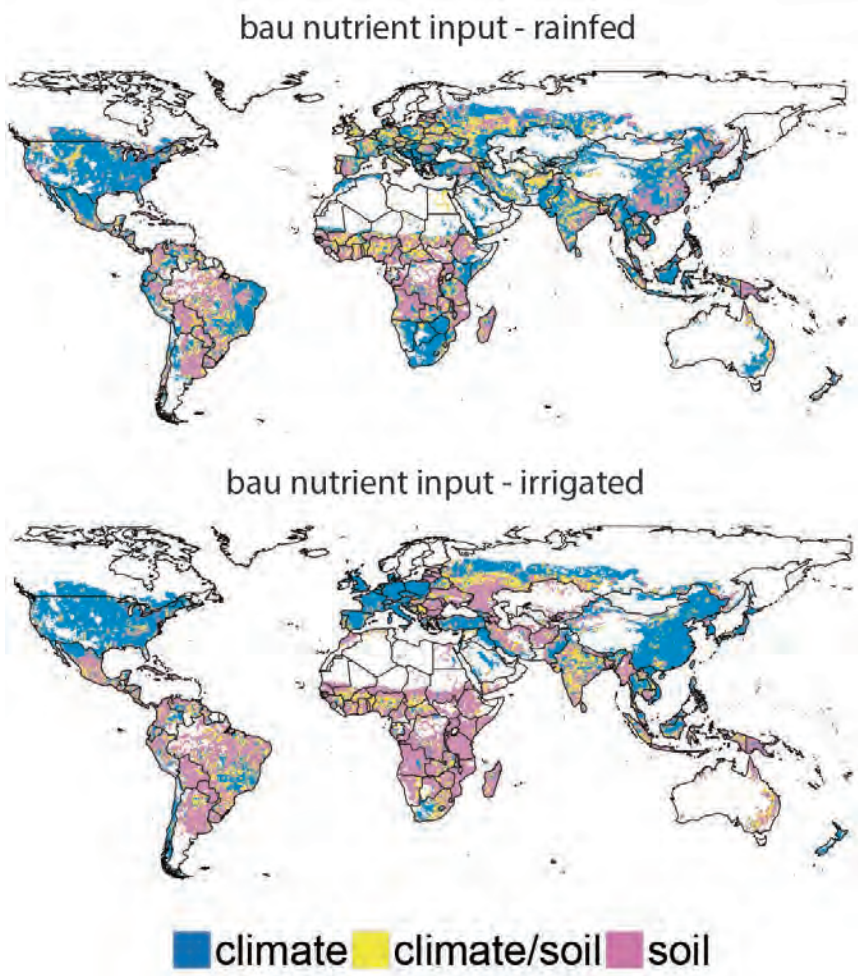
As the population increases and climate change progresses, food security is becoming a pressing issue around the world. To help tackle the challenges we face, IIASA researchers have used agricultural models that estimate how much of a crop can be produced in a certain amount of space. Along with investigating the effects of agricultural intensification, the team also demonstrated the pressing need for better soil data to help improve projections of future crop yields.

To examine how food security might change around the world, the IIASA Ecosystem Services and Management Program used its Environmental Policy Integrated Model to examine how agricultural intensification will affect the productivity of the world's main crops as well as its environmental effects, such as changes to the levels of nutrients, water, and organic carbon stored in the soil. In turn, this research was used to inform another of the program's integrated models, the Global Biosphere Management Model, which is used to analyze the competition for land use between agriculture, forestry, and bioenergy.

In further work, carried our as part of the Agricultural Model Intercomparison and Improvement Project, the team showed that incorporating accurate data on soil type in such models is vital. The study was the first global assessment of the importance of soils in global crop models and showed that the effects of soil type can often outweigh the effects of weather variability—such as year to year changes in rainfall and temperature [1].

This is because soils have the capacity to amplify or buffer climate impacts, for example through the provision of water during the early stages of a drought. In extreme cases, climate change impacts on yield were either negative or positive depending on the soil type chosen for the simulation, the researchers found. In particular, for yield projections in regions that use little fertilizer or irrigation—often poorer regions with many small farms—crop yield variability related to soil type can be larger than yield variability due to weather. In places where farmers use a large amount of fertilizer, the impact of soil type was smaller.

In addition, global crop models often do not include soil management for climate resilience, nutrient management, or erosion control, all factors that can affect yield. Better soil data could therefore substantially improve projections of future crop yields, the researchers conclude.



Grid cells in which climate or soils dominate maize yield variability assuming business-as-usual fertilization, and rainfed (top) and irrigated (bottom) production systems.

IIASA by program

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Ecosystem Services and Management Program

Collaborators

- European Commission DG Joint Research Centre, Italy
- United States Department of Agriculture, USA
- University of Chicago and Argonne National Laboratory Computation Institute, USA
- Helmholtz-Zentrum Geesthacht, Germany
- Potsdam Institute for Climate Impacts Research, Germany
- University College London, UK
- University of Colorado Boulder, USA


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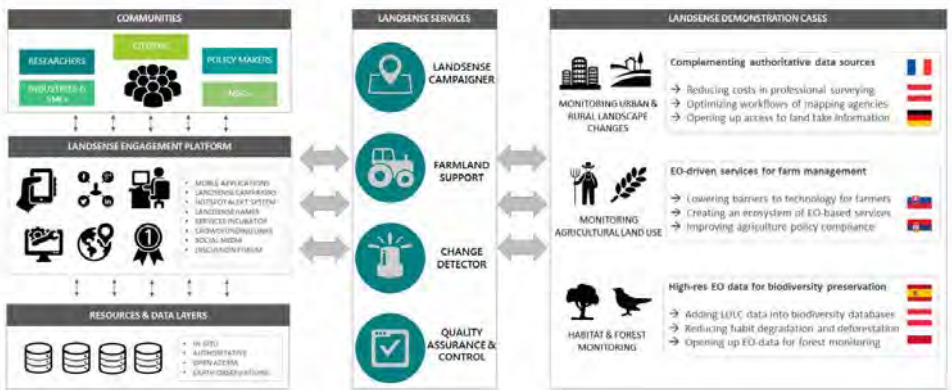
Harnessing the power of citizen science

Land-use change can have far-reaching impacts on issues as broad as flood resilience, food security, air pollution, and biodiversity protection. Monitoring it is therefore crucial, and one effective and cheap way to do it is to engage citizen scientists. In 2016 the IIASA Ecosystems Services and Management Program furthered its pioneering work in citizen science, exploring how to encourage people to take part, assessing the quality of the data, and launching a citizen science observatory.

In 2016, a new IIASA-led project, *LandSense*, was launched to link remote sensing with citizen-science data collection. The citizen science observatory includes an engagement platform that hosts various services and tools for collecting and sharing data from satellites and citizens. The citizen science campaigns run by the project will help monitor resources in both urban and rural contexts, in select regions of Austria, France, Germany, Spain, Slovenia, and Serbia, as well as beyond Europe in Indonesia.



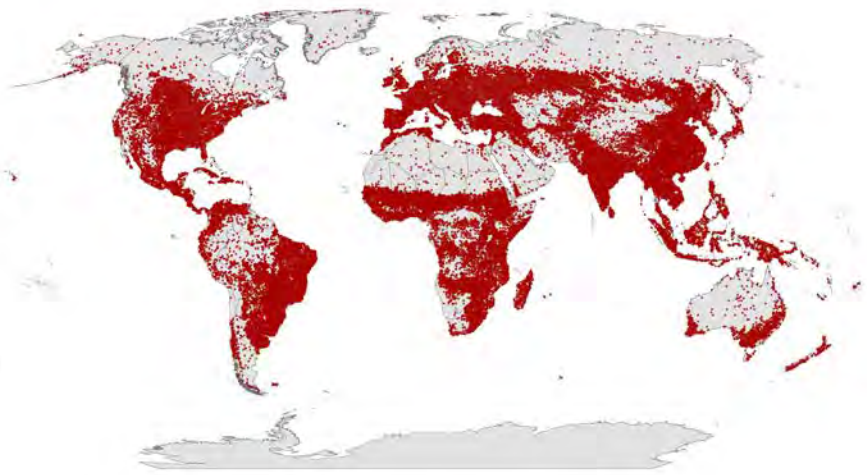
The concept underpinning the LandSense Citizen Observatory

Citizen science data can play an important role in long-term, accurate monitoring of agricultural production—crucial to policies to increase food security and reduce food price volatility. In 2016, as part of the EU-funded *Stimulating Innovation in Global Monitoring of Agriculture* project, IIASA researchers helped validate and improve a key map of cropland distribution using its suite of crowdsourcing land cover tools, collectively known as Geo-Wiki.

Two key concerns when using citizen science data for such purposes is the quality of the data and the need to engage a large number of people. The Land Use Cover Area Frame Sample is an EU land-cover and land-use change survey, which takes place every three years. The data needed can be collected by citizens, using the IIASA-developed mobile phone application FotoQuest Austria, for example. However, the quality of the data was in question.

As part of the European Research Council-funded project *Crowdland*, IIASA researchers compared the data collected by the citizens with those of the professional surveyors. The results showed that both land cover and land use could be crowdsourced with an accuracy of about 80%. This represents a new source of potentially valuable information for the validation of land cover maps, is much cheaper than a professional survey, and has the advantage that the data can be collected continuously over time.

Motivation among citizens, however, is very uneven. Mobile applications that involve user-generated content generally have 90% of the content provided by only 1% of the users. Of those remaining, 9% of users provide content some of the time while 90% use the content but do not contribute anything [1].



Validation data gathered in the SIGMA crowdsourcing campaign

The IIASA Ecosystem Services and Management Program has run three campaigns to increase the percentage of users providing content. For Picture Pile, contribution to the science was the only incentive, but for FotoQuest Austria small prizes were also introduced. For Geo-Wiki, Amazon vouchers and coauthorship on a scientific publication led to rapid uptake by users. Rapid feedback and regular interaction with the participants was also a key part of this campaign and had noticeably positive effects on participation.

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Ecosystem Services and Management Program

Collaborators

The SIGMA project is led by the Belgian company VITO with a consortium of 22 EU and international partners

LandSense is led by IIASA with a consortium of 17 EU partners including 5 research institutes/universities, 5 small medium enterprises, 3 NGOs, 3 government bodies and the European Citizen Science Association, a list of collaborators can be found here.

Building security for farmers in Ethiopia

Smallholder farmers in Ethiopia are especially vulnerable to the threats of climate change, but by expanding irrigation, providing subsidies for fertilizers, and investing in infrastructure, policymakers can improve smallholders' income and food security, IIASA research has shown. The work also provided input to the Global Biosphere Management Model, leading to insights into the effects of different policy measures regarding food security and poverty.

In Ethiopia, 84% of the population lives in rural areas, where they produce 90% of the country's grain with, on average, less than one hectare of land per person. A rapidly increasing population, along with climate-related disasters like droughts, and competition for land, water, and energy, are threatening livelihoods and food security in the country.

In a study funded by the International Fund for Agricultural Development (IFAD), IIASA researchers from the Ecosystems Services and Management Program set out to map the distribution of different types of smallholder farms in terms of poverty and food security. The team developed a new methodology based on: agro-ecological zone (i.e., biophysical environment and climate), farm size, main activities, and intensity of production.

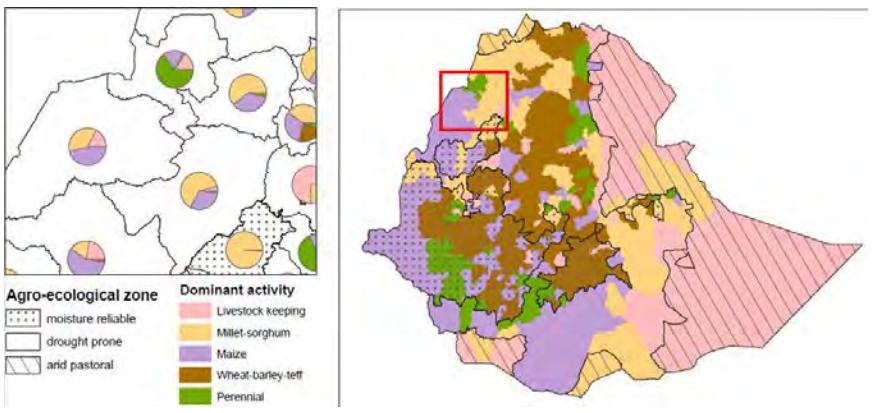
The researchers analyzed the effects of three policy interventions on poverty and food security:

1. the development of infrastructure networks to improve access to markets;
2. the development of irrigation infrastructures to increase production;
3. fertilizer subsidies to increase production.

Overall, a combination of irrigation expansion with infrastructure development and fertilizer subsidy would be most beneficial for smallholder income and overall food security, the researchers found. The results showed that livestock-oriented systems are less profitable than crop-oriented systems and more prone to food-insecurity.

This work, valuable in itself, also served as input to the IIASA Global Biosphere Management Model. This country-specific, household-level data improved the model in terms of both its production and consumption analyses. For Ethiopia, it meant that farming systems could be modeled in such a way that allows for transitions from one type of farming system to another, important for assessing the policy options of the future.

The results were used to provide support to Ethiopian policymakers, as well as helping to define the most suitable locations for irrigation schemes in the second phase of an IFAD project, the *Participatory Small-Scale Irrigation Program*.



Dominant combinations of activities and agro-ecological zone by district (known as woreda in Ethiopia) (right) and the distribution of farming systems for the subset in the red rectangle (left).

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Ecosystem Services and Management Program

Collaborators

- Research and Impact Assessment Division, International Fund for Agricultural Development, Italy


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Facing climate change in West Africa

Climate change is likely to hit West Africa hard, potentially affecting the livelihoods of millions of people. The IIASA Ecosystems Services and Management Program has worked closely with local stakeholders to develop possible climate strategies, showing that low investment in agriculture will leave the region particularly vulnerable.

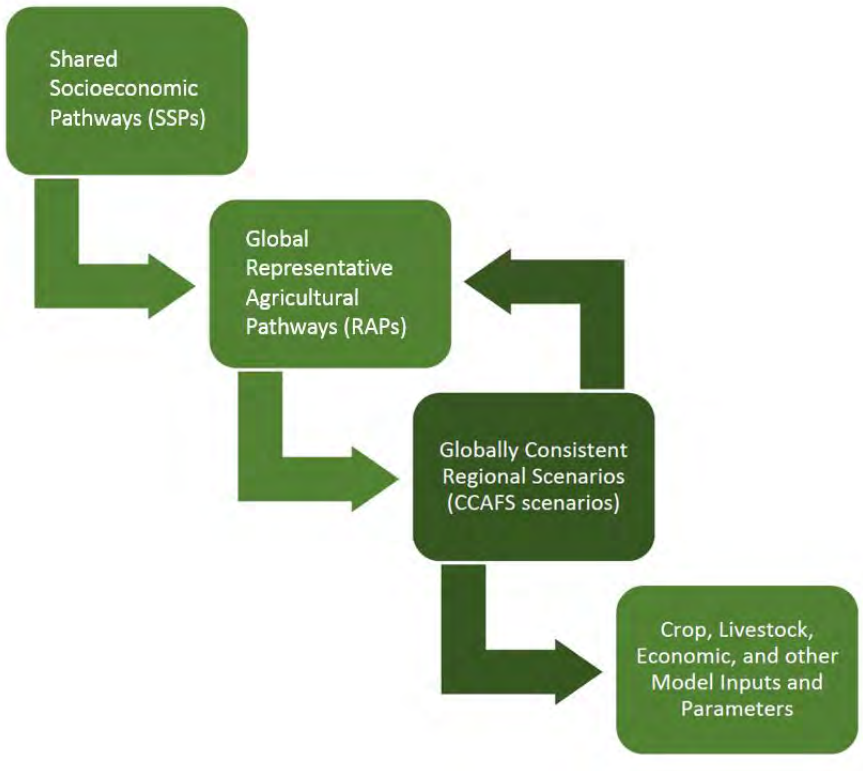
West Africa is a major producer of crops such as cassava, millet, and sorghum but climate change could mean regional production is not able to meet the growing demand for food and livestock feed. To help policymakers develop robust climate strategies, IIASA researchers built scenarios, or future pathways, and applied the institute's Global Biosphere Management Model alongside the International Model for Policy Analysis of Agricultural Commodities and Trade developed by the International Food Policy Research Institute [1].

The results show that investments in agriculture in the region, specifically to improve crop yields, could lead to greater food production. However, it could also create land trade-offs: agricultural expansion in West Africa will encroach into forest and other natural land, but it will also reduce the need for agricultural land globally. In some cases, for each hectare of land converted to agriculture in the region three times as much land could be spared in other areas [2].

To develop the scenarios for the work, the team worked closely with local experts to develop plausible futures for the region. Then they linked the scenarios with the new global socioeconomic projections developed for climate change research—the Shared Socioeconomic Pathways [3] —and adapted them to provide specific information for West Africa. This resulted in the first globally coherent, regionally relevant Representative Agricultural Pathways.

In order to create scenarios that would be useful for regional planning, the researchers conducted extensive meetings with policymakers, farmers, and other stakeholders to gain an understanding of the many factors driving agricultural production in the region.

The study resulted in a package of scenarios specifically designed for West Africa to the year 2050, which include climate change as an unavoidable outside force. The scenarios provide descriptions of potential future developments, including narratives as well as quantitative projections for factors such as population, economic growth, deforestation, land use, food production, and trade.



Globally consistent regional scenarios.

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Ecosystem Services and Management Program

Collaborators

- International Food Policy Research Institute, USA
- CGIAR Program on Climate Change Agriculture and Food Security, Denmark
- Environmental Change Institute, University of Oxford, UK

Shaping European bioenergy policy

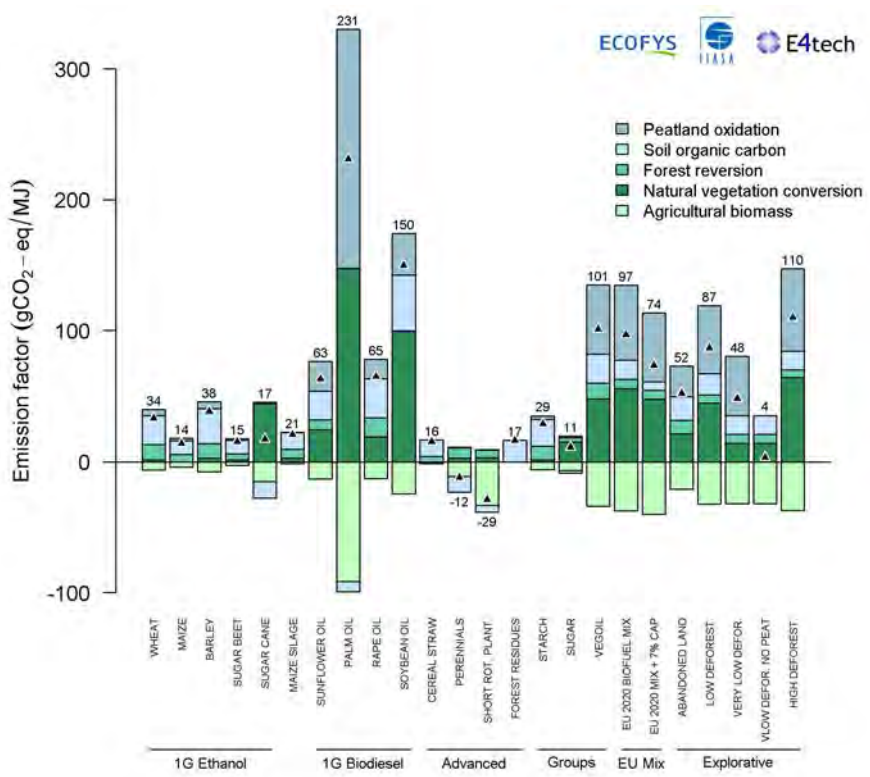
Bioenergy was once hailed as a key part of tackling climate change but there have been rising concerns over how efficiently it can reduce greenhouse gases emissions and the amount of land it requires. The IIASA Ecosystems Services and Management Program has been analyzing these issues for the European Commission, helping to shape EU policies.

In the EU, the use of bioenergy is on the rise. This is partly due to an increased focus on renewable energy, intended to reduce greenhouse gas emissions and increase energy security. However, biofuel production can occupy land that would otherwise be used to grow food and feed. This displacement can lead to deforestation when other areas are converted to agriculture, threatening biodiversity and offsetting some of the climate benefits.

In a study for the European Commission, IIASA researchers assessed the impacts of different biofuels on land-use change and climate. On one end of the spectrum, the study showed that certain types of vegetable oils, such as palm or soybean oil, can lead to significant greenhouse gas emissions. And on the other end, second generation biofuels— produced from waste such as forestry residues left after logging or cereal straw—showed a good performance overall, with several cases of net negative emissions.

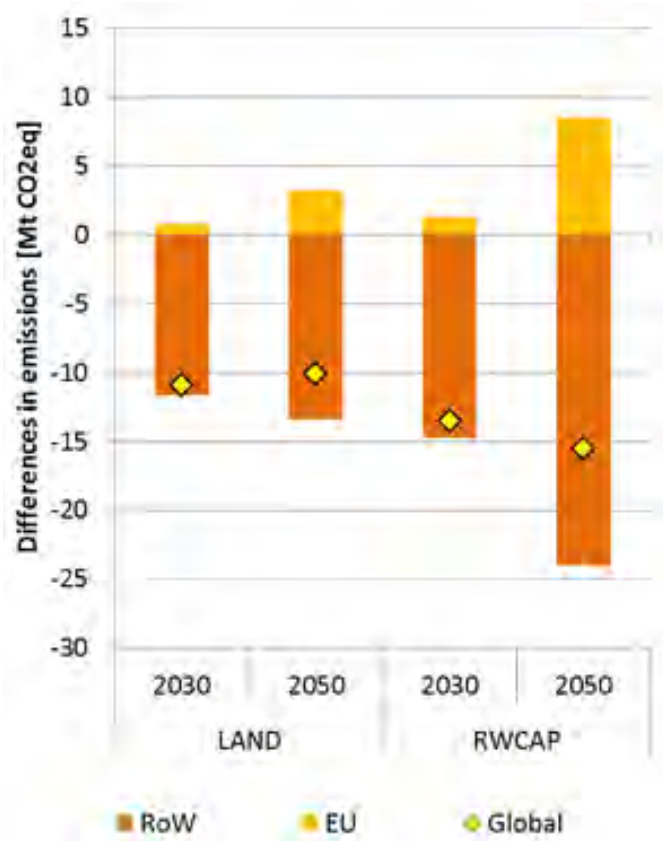
The study was used as important input to the 2016 proposed revision of the EU Renewable Energy Directive. Under the new proposal, starting in 2020, the European Commission intends to promote advanced biofuels that do not compete with food, and to progressively phase out crop-based biofuels from the EU energy consumption.

In other work on biofuels, the European Commission asked a group of researchers led by IIASA to assess how increasing bioenergy demand would affect forests, the forestry industry, and other sectors that rely on biomass.



Emission intensity of different biofuel feedstock consumed in the EU and analysis of impact of some policy mixes

The team showed that increased demand would place increased pressure on forest ecosystems and their resources, both in and outside of Europe. However, worldwide protection for biodiversity and land with high carbon storage could lead to global greenhouse gas emissions from the land-use sector 10 metric megatons lower than without protections.



Differences in global land-use net emissions for the Land and Roundwood Cap scenarios in comparison to a reference scenario. The Land scenario represents a case where land criteria are implemented to restrict biomass harvests in areas with high biodiversity value and/or high carbon stocks, and the Roundwood Cap scenario represents a case with the same land criteria as well as a cap on the use of roundwood for energy.

Using these IIASA analyses, the European Commission proposed a number of revisions to the Renewable Energy Directive to ensure that bioenergy achieves robust and verifiable emissions savings.

Further work for the European Commission concerned the importance of the EU's land-use sector as a carbon sink. Following the Paris climate agreement, the European Commission published a proposal to include the land-use sector in its emission-reduction commitments. The commitments, as well as their breakdown to individual countries—known as the "Effort sharing Regulation"—were based on research and modeling work conducted at IIASA using the Global Biosphere Management and Global Forest Models.

Based on IIASA analyses, the European Commission proposed to allow member states to use up to 280 metric megatons of CO_2 of land-use sector credits—from afforestation or grassland management—from 2021-2030 to achieve their mitigation targets. This should provide additional incentives for mitigation in the land-use sector.

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Ecosystem Services and Management Program

Collaborators

- Air Quality and Greenhouse Gases Program, IIASA
- National Technical University Of Athens, Greece
- EuroCare, Germany
- Indufor Oy, Finland
- Institute for European Environmental Policy, UK
- Öko-Institut e.V., Germany
- European Forest Institute, Finland
- European Commission
- Ecofys, Netherlands
- E4tech, UK

Further information

- Impact Assessment LULUCF
- Proposal for an Effort Sharing Regulation 2021-2030
- Impact assessment of the revised renewable energy Directive
- EU biofuels study


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Using carbon markets to tackle climate change and protect forests

Under the UN program on Reducing Emissions from Deforestation and Forest Degradation (REDD), forest owners can pledge to protect their forest, and sell those pledges to electricity producers to offset their emissions. A clear indication that the price of carbon emissions will rise in the future, combined with a benefit-sharing mechanism that ensures forest owners will not lose out under rising carbon prices, could increase participation in the scheme, IIASA research has shown.

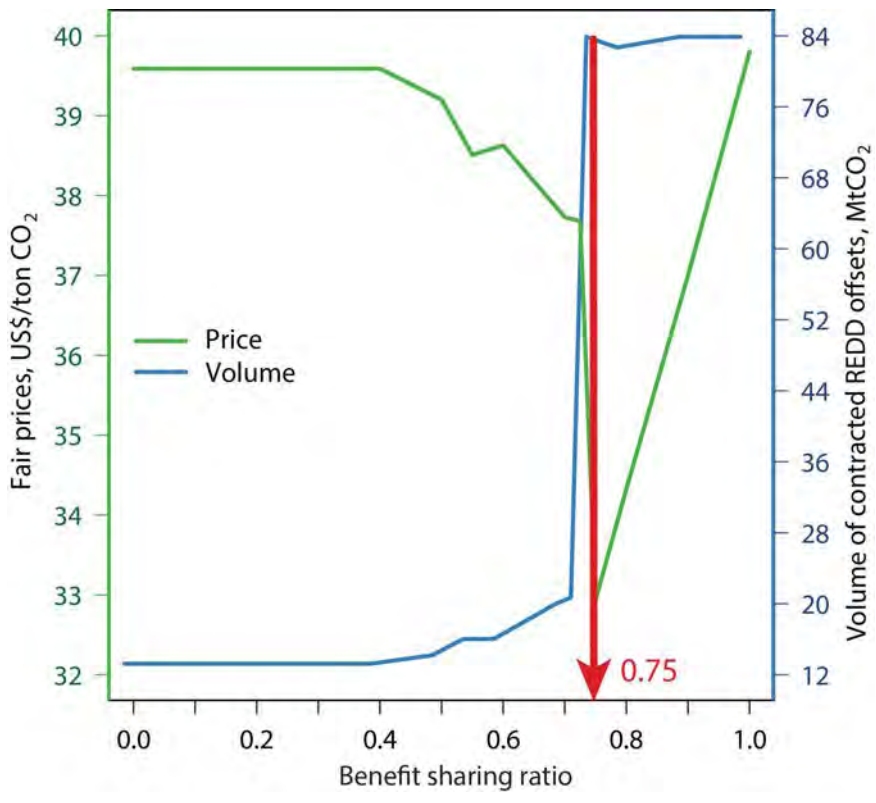
The UN REDD program aims to mitigate climate change through protecting forests in developing countries. Halting deforestation in this way means that the important carbon storage that forests provide is protected. Under REDD, a forest owner is given a certificate for each hectare of forest that they protect from logging (therefore avoiding CO_2 emissions). These can be sold to carbon emitters, such as energy producers, who can use them to offset their emissions.

At the moment, because the price for carbon emissions is very low, the best strategy for an electricity producer is to buy the bare minimum number of certificates. However, if they suspect that the price of carbon will increase, they may choose to buy more than they need, selling any excess at a profit in the future.

Researchers from the IIASA Ecosystems Services and Management Program investigated how to improve participation in the REDD certification program, by forest owners (sellers) and electricity producers (buyers) alike [1]. In particular they examined the impacts of a 'benefit-sharing mechanism.' Under such a scheme the forest owner would share in the profits that are made if the certificates are sold by the electricity producer at a profit. This reduces the forest owner's risk, since they do not lose out if the certificates are sold on at a much higher profit in the future.

The results showed that risk-averse attitudes could help get the scheme off the ground. This is because a cautious electricity producer would want to protect themselves against a rise in the price of carbon emissions by buying certificates. And a benefit sharing scheme could encourage a risk-averse forest owner to sell their certificates, since they will not lose out under a price hike for emissions.

To bring out these behaviors policymakers should give a clear indication that carbon prices will increase, and implement a benefit/risk sharing mechanism, the researchers conclude.



The impact of the benefit-sharing ratio on the contracted amount of REDD offsets. At every value of benefit-sharing ratio expected utilities of the forest owner and electricity producer stay the same, but the contracted amounts (blue line) and equilibrium prices (green line) differ.

IIASA by program

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Ecosystem Services and Management Program

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- London School of Economics, UK

Further information

- Delivering Incentives to End Deforestation: NORAD DITED project
- The project "Options Market and Risk-Reduction Tools for REDD+" is funded by the Norwegian Agency for Development Cooperation under agreement number QZA-0464QZA-13/0074
- EU's Seventh Framework Programme grant agreement no. 603906 (ECONADAPT).

Energy Program

The current unsustainable use of energy is the source of major environmental, social, and economic challenges. Energy Program research spans many domains, including research in energy security, energy and poverty, and energy-environment links, and adopts a holistic and integrated perspective. A main strength of the program is its ability to understand salient trade-offs and synergies between multiple policy priorities and objectives in different sectors.

Program website
Scientific recognition
Publications
Staff
Events

Objectives

- Develop the next generation of the program's integrated assessment Model for Energy Supply Strategy Alternatives and their General Environmental Impact (MESSAGE) with an improved representation behavioral change, uncertainty, and the energy-water-land nexus.
- Develop and quantify a new conceptual framework for energy poverty, moving from energy access to a broader definition of energy for human wellbeing.
- Research political factors and how they shape energy system transformations.
- Further establish the Energy Program as a leader in the scientific community, coordinating major international research projects and serving as a hub for important community datasets and services.
- Develop interactive web-based policy tools and hold regular stakeholder workshops, fostering the science-policy dialogue on energy sustainability.
- Establish a broad capacity-building platform with key partners from the G20 countries (with a focus on the co-benefits of climate and development policies).

Selected highlights

Shared Socioeconomic Pathways: Finding routes to sustainability

Energy and the Sustainable Development Goals

Guiding science and policy to robust climate action

Smart policies for sustainability

Adopting sustainable technologies: New methods for a new world

Why do renewables grow faster in some countries than others?

Shared Socioeconomic Pathways: Finding routes to sustainability

How will the challenges of climate change evolve given the different social, political, and economic paths that the world might take? The Shared Socioeconomic Pathways provide possible narratives, allowing the climate research community to systematically compare their projections and develop robust policy advice. These pathways were the subject of a 2016 special issue of the journal *Global Environmental Change*, compiled by the IIASA Energy Program and partners.

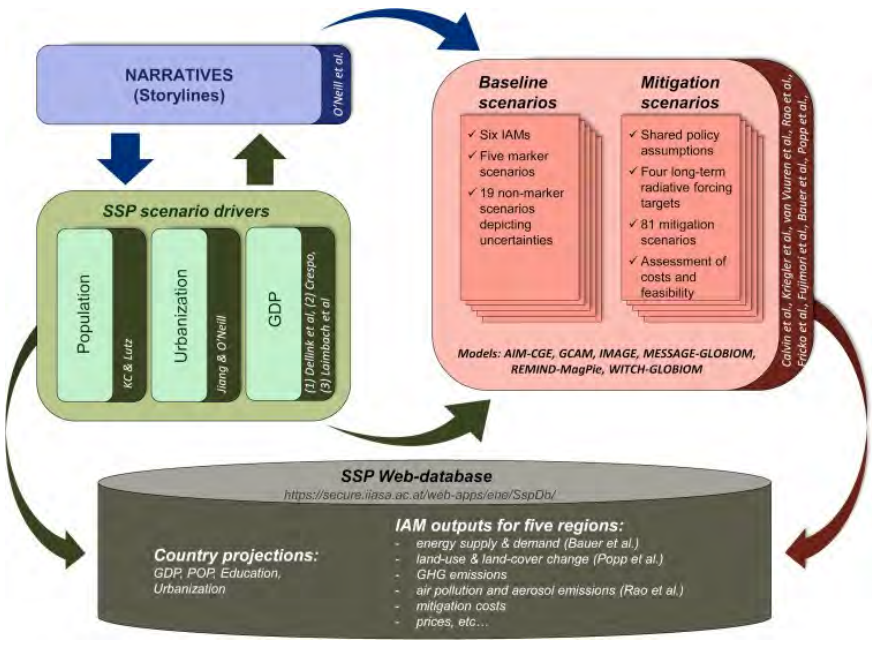
The Shared Socioeconomic Pathways (SSPs) are five possible paths human societies could follow over the next century. Designed by and for the climate change research community to use as a basis for their models, the SSPs span a wide range of feasible future developments in areas such as population, the economy, and agriculture.

The pathways were developed in recent years to describe plausible major global developments that together would lead to different challenges for mitigation and adaptation to climate change. The SSPs are based on five narratives describing alternative socioeconomic developments, known as: sustainable development, regional rivalry, inequality, fossil-fueled development, and middle-of-the-road development.

Analyzing the different ways to mitigate climate change as part of the special issue, the researchers found that the costs of mitigation were lowest in the sustainable development and inequality scenarios and highest in the fossil-fueled development and regional rivalry pathways.

Perhaps most importantly, the studies find that not all targets are necessarily attainable from all of the pathways. Specifically, keeping temperature change to about 2°C was not feasible when following the regional rivalry pathways. This narrative describes a possible future where resurgent nationalism, concerns about competitiveness and security, and regional conflicts push countries to increasingly focus on domestic or, at most, regional issues.

The next steps of the process, organized as part of the Scenario Model Intercomparison Project [1], will involve collaboration with the climate modeling teams of the Coupled Model Intercomparison Project 6 [2] to assess the climate consequences of the SSPs. The work also provides important services to the research community, including a detailed modeling protocol for integrated assessment modeling teams to enable widespread participation in quantifying the SSPs.



The main steps in developing the SSPs, including the narratives, socioeconomic scenario drivers (basic SSP elements), and SSP baseline and mitigation scenarios.

Most importantly, the SSPs enable researchers to explore climate change impacts, adaptation, and vulnerability under a range of possible socioeconomic developments and climate change projections. The pathways provide a common grounding so that a large body of literature based on comparable assumptions can emerge.

Energy Program

IIASA by program

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Energy and the Sustainable Development Goals

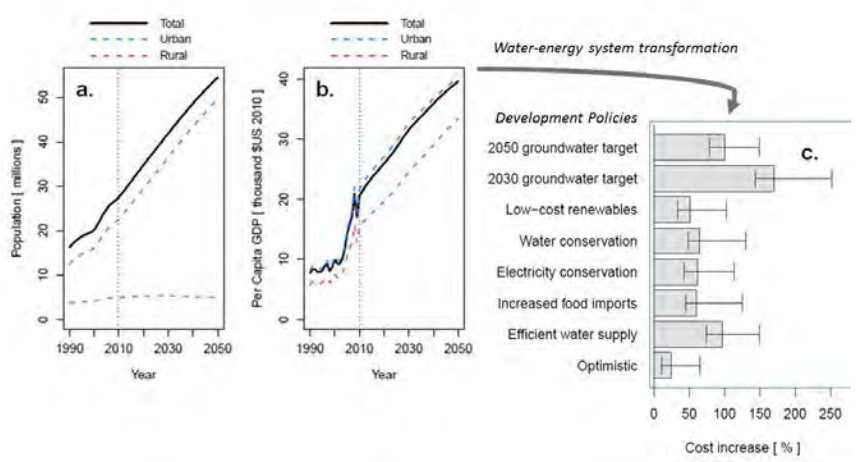
In exploring the complex interplay between climate action and sustainable development, the IIASA Energy Program (ENE) has assessed what makes climate policies effective. Specifically the researchers have explored the interaction of climate policy with a host of other policy objectives, including the implications for water and energy security.

Designing effective policy is crucial if we are to avoid catastrophic climate change. To determine what works, researchers from the *Linking Climate and Development – Leveraging International Networks and Knowledge Sharing* (CD-LINKS) project examined 19 case studies. Barriers to policy success included a lack of money and required infrastructure, or contractual challenges when many parties needed to establish business relations. When it came to the interaction of climate and sustainable development, many cases—especially those in developing countries—showed that other aspects of sustainability, such as reducing air pollution, were the drivers behind policies and climate mitigation was essentially a co-benefit.

Through collaboration with international modeling teams (in Brazil, China, the EU, India, Japan, Russia, and the USA) the CD-LINKS project has also developed transformation pathways that coincide with national contexts but at the same time are consistent with the Paris Agreement objectives of limiting temperature change to 1.5-2°C.

Limiting temperature change in this way will require a transformation of the global energy system. However, different climate-friendly energy technologies require varying amounts of water, and therefore such a transition could have a substantial impact on water demand. To examine these impacts, ENE enhanced the Model for Energy Supply Strategy Alternatives and their General Environmental Impact (MESSAGE) to account for energy-related water use. After applying the model to a range of scenarios, all of which would ensure a 2°C limit [1], the researchers demonstrated that strategies combining improved energy efficiency with a rapid scale-up of solar and wind power generation can yield climate stabilization, reduced water demand, and improved water quality.

A case study on the Kingdom of Saudi Arabia illustrated the critical need of balancing water use and climate objectives on the national level. In Saudi Arabia, a transition away from groundwater use by the year 2050 could increase national electricity demands by more than 40% relative to 2010 conditions. Simon Parkinson and colleagues conclude that the increase in energy demand would be primarily due to the expansion of energy-intensive desalination and water conveyance [2][3].

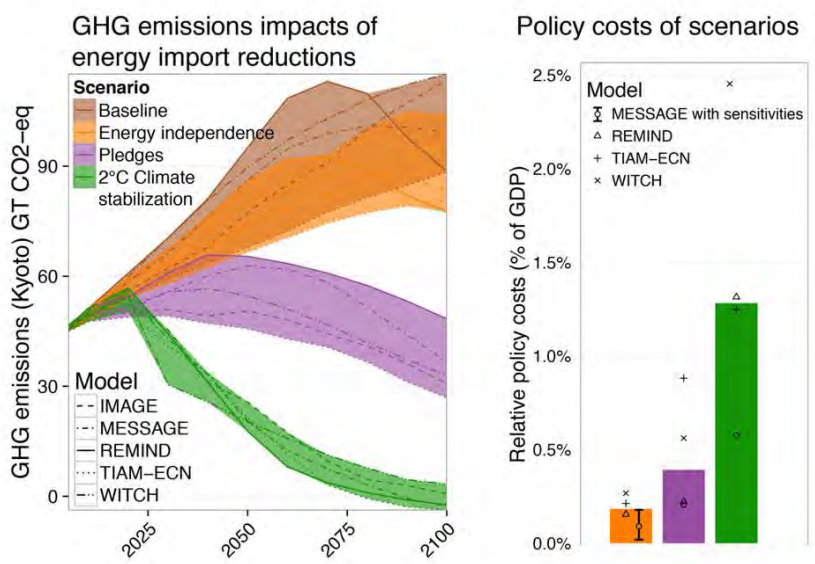


Economic impacts of combined climate and groundwater policies in Saudi Arabia. a. Population to 2050; b. Income to 2050; c. Cost for combined water-energy system development relative to a case no groundwater or climate targets [2].

Another study examined the impact of energy imports on greenhouse gas emissions. While it has been established that energy imports would fall if greenhouse gas emissions were reduced, the team wanted to know if emissions fall when energy imports are restricted.

The results showed that while emissions reductions generally benefit energy security—by reducing energy imports—policies focusing on energy security do not show the same co-benefits for climate targets. In fact, policies to reduce energy imports would only lower emissions enough to limit warming to roughly 3.5°C to 4°C.

The study also compared the relative costs of energy independence and climate policies. Reducing energy imports would cost between 3 and 20 times less than stabilizing climate change at 2°C by 2100, but would be comparable to the cost of the climate pledges. Thus, while climate policies can lead to lower energy imports, these can be reduced more cheaply through energy import restrictions.



The impacts of energy import restrictions on greenhouse gas emissions and the relative costs of energy independence and climate policies.

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Energy Program

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- Pacific Northwest National Laboratory, USA
- Korea Advanced Institute of Science and Technology, Republic of Korea
- European Commission Joint Research Centre

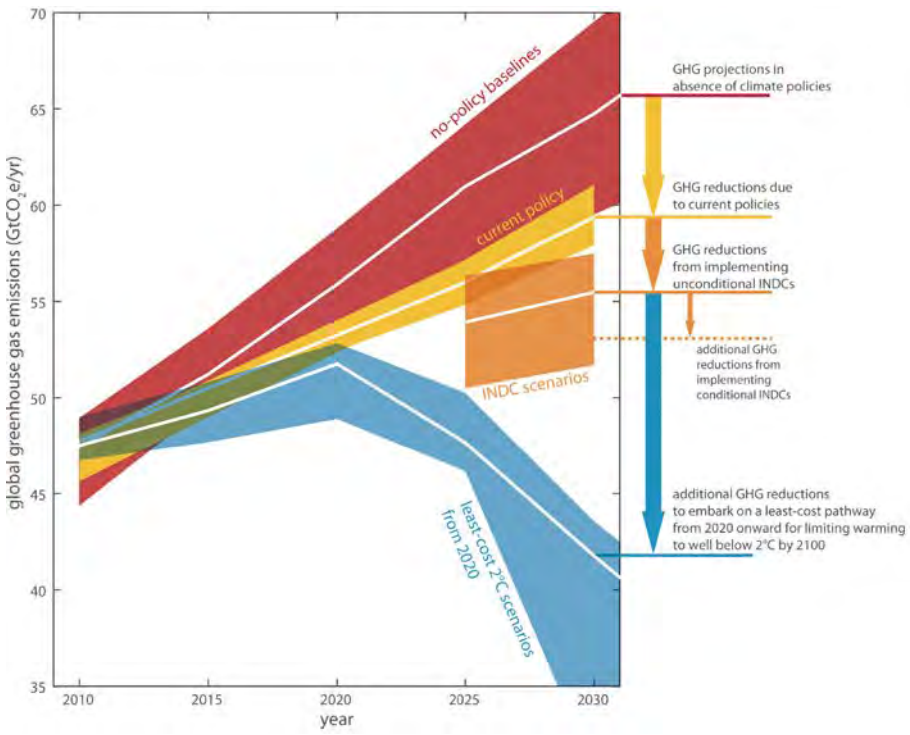
Guiding science and policy to robust climate action

International climate policy requires scientific evidence to steer it towards robust outcomes. In 2016, the IIASA Energy Program (ENE) worked to provide this by assessing what it will take to meet goals of the Paris climate agreement, whether national climate pledges live up to those ambitions, and how to ensure that future research yields policy-relevant results

The Paris Agreement set a target of limiting warming to well below 2°C and further pursuing efforts to limit it to 1.5°C. To understand where we are starting from, ENE researchers carried out a meta-analysis of the current emissions reduction pledges and whether they can achieve the Paris Agreement's goals [1].

The current pledges fall significantly short of putting the world on track to the goals, the results show (see figure). The work also highlighted the fact that the relatively weak pledges in the current agreement may result in a greater reliance on controversial technologies such as bio-energy combined with carbon capture and storage to make up the shortfall in the near term.

Along with the absolute emissions' savings, the equity of the current pledges is also a key issue. In a further study, IIASA researchers revealed that not only are current pledges not sufficient, they do not spread efforts fairly amongst countries [2].



Assessment of current Paris Agreement emissions reduction pledges. Current pledges (orange) fall far short of pathways that can limit warming to below 2°C with at least a two-out-of-three chance (blue range). Adapted from [1].

To create truly effective climate policy it is important that policymakers are aware of the non-negotiable limits that they must abide by to prevent dangerous rises in temperature. To shed light on these "geophysical limits" IIASA researchers examined a case where there was a greater than two-out-of-three chance that warming was limited to below 2°C. To achieve this, global CO_2 emissions from 2016 onwards should not exceed 590–1,240 billion tons of CO_2, the researchers found [3].

Oil resources and their markets play an essential part in climate change mitigation. In a 2016 study, ENE researchers demonstrated that sustained high or low oil prices could have a substantial impact on CO_2 emissions. In fact, the two price extremes could result in an increase or decrease in emissions of 55-194 gigatons of CO_2 by 2050 —amounting to 5-20% of the cumulative emissions allowable for keeping temperature change under the 2°C threshold.

When oil prices are high, there is an effect on demand, as consumers increase efficiency to save money. However, the emissions savings are not larger than one would expect because at high oil prices other carbon-intensive fuels, such as coal, are more likely to be used— either for electricity or liquid fuel production. The team found that the emissions impact depends not just on future oil prices, but other uncertainties such as whether oil and gas prices decouple going forward; the future potential of sustainable bioenergy supplies; and the costs and availability of electric vehicles.

If the goal is to mitigate carbon substantially, the researchers conclude, high oil prices offer no substitute for climate policies [4].

Finally, in the afterglow of the Paris Agreement, many important, policy-relevant questions arose. However, these questions were often unclear to scientists without a strong understanding of policy. Capitalizing on its expertise at the science-policy interface, ENE published two perspective articles that will help catalyze policy-relevant research. One piece directly addressed the geoscience research community [5], while a second targeted the broader global environmental change community, with a focus on the Paris Agreement's temperature goal [6].

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Energy Program

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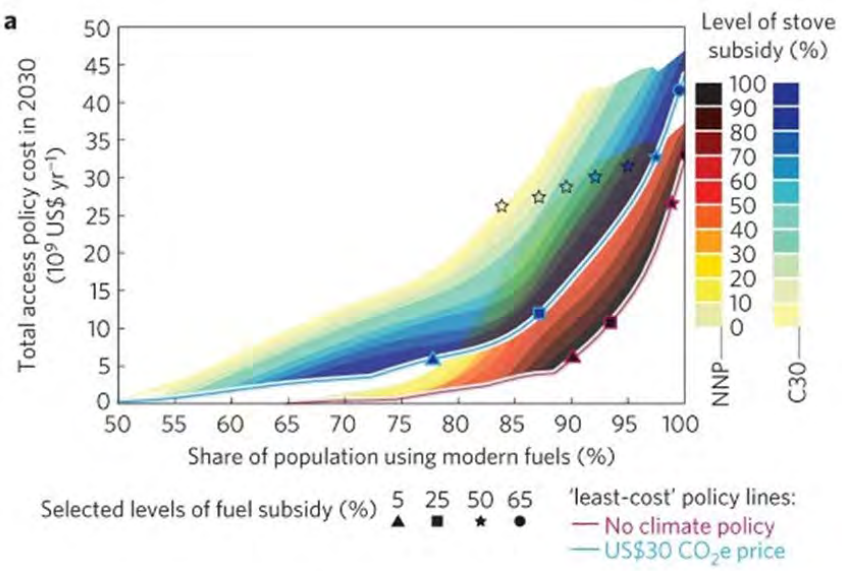
Smart policies for sustainability

Effective climate policy is a vital sustainability goal but it must also be balanced against improving energy access and reducing poverty. For instance, unless they are carefully designed, new climate policies in Asia could push access to modern energy out of reach for millions in the region, research from the IIASA Energy Program (ENE) has found. The team also examined how eliminating poverty will affect energy use and greenhouse gas (GHG) emissions.

The Sustainable Development Goals aim to achieve universal access to modern energy by 2030—but they also call for urgent action to combat climate change. An ENE study focused on this issue in South Asia, where 72% of the population relies on solid fuels for cooking—causing air pollution and related health problems. It showed that by 2030 that could be reduced to 35% on the current trajectory. But with climate policies and no energy access policies, 336 million people would be unable to afford the switch modern fuels [1].

A further study examined kerosene subsidies, initially designed to help those without electricity but now hampering the shift to clean energy. In India 64% of kerosene used for lighting is supplementary to electricity, the research showed, which means that simply increasing electricity access without improving reliability will only reduce the kerosene used by a small amount [2]. Instead, eliminating subsidies by 2030 could reduce kerosene use by 97%, and would also benefit the economy, since the deadweight loss—a measure of economic inefficiency—of the subsidy is US$200–950 million. The solution, the researchers say, is to shift subsides towards improving electricity reliability and cleaner lighting technologies.



Energy access policy cost-effectiveness under baseline and climate mitigation scenarios [1].

Addressing energy access, however, is only a first step in combating energy poverty. The *Decent Living Energy* project goes beyond energy access and aims to quantify the energy needs and related climate change impacts of eradicating poverty and providing decent living standards to all.

Under the project, ENE researchers clearly defined for the first time the material requirements needed for human wellbeing. These include things in the home, such as food and cooking equipment, but also extend to societal level, including the infrastructure needed, such as roads. The definition helps policymakers set fair wages and quantify environmental impact [3].

To understand how eliminating poverty will affect energy use and GHG emissions, researchers also examined how household consumption and energy use increases with rising income.

One study examined what makes people more likely to own household technologies like washing machines, which use a lot of electricity. Examining data from IIASA member countries Brazil, India, and South Africa, they found that the appliances people buy depend not only on their income, but also factors such as race, culture, and wealth in terms of assets like cars, which can secure loans when income alone cannot [4]. A second analysis, using carbon footprinting for Brazilian and Indian households, revealed that the amount of energy used through consumption is largely constant across income groups. This challenges conventional wisdom that poverty eradication would cause a large increase in emissions [5].

Finally, the team investigated how living standards rise with economic growth. As incomes increase in developing countries, access to amenities such as electricity, clean cooking energy, water, and sanitation also improves but not uniformly, and not as quickly as income growth [6][7]. Access to clean cooking energy and sanitation lagged behind access to electricity and water, a finding which has an outsize impact on the poorest, especially women.

Energy Program

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Collaborators

- Research for the Nature Energy article was done with funding support from the project *Advanced Model Development and Validation for Improved Analysis of Costs and Impacts of Mitigation Policies*.
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Further information

MESSAGE-Access model


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Adopting sustainable technologies: New methods for a new world

The transition to a sustainable energy system will require profound changes across almost every aspect of society, from individual choices to government policies. To aid this transition the IIASA Energy Program (ENE) has worked to enhance global energy-economy models, providing insights into the investments needed to deploy a large share of wind and solar technologies in power systems, and the role of consumer preferences in adopting sustainable transport.

Renewable energy technologies such as wind turbines and solar photovoltaics are deemed essential to creating a sustainable energy system; however, they can be intermittent and it is not possible to adjust their power output to order. This means that power systems with significant deployment of this "variable renewable energy" will likely need more backup capacity to ensure peak demand, more flexibility to address increased fluctuations in power supply, and more energy storage or power-to-gas technology to absorb the excess energy generated at times.

The costs of implementing these changes may be significant, and assessments of low-carbon futures must account for them. However, global energy-economy models are not detailed enough to directly assess impacts due to mismatches between electricity supply and demand that can occur from one minute to the next. To address this, ENE researchers used the Model for Energy Supply Strategy Alternatives and their General Environmental Impact (MESSAGE) to simulate the impacts and costs of the integration of variable renewable energy, providing estimates of the magnitude and duration of the load that must be provided by technologies that *can* adjust their power output to order.

The model indicates that there will be a significant reduction in the use of non-renewable power plants with a diminishing role for traditional generators, such as nuclear and coal, and a transition to more flexible technologies. The results also highlight the importance of electricity storage and hydrogen electrolysis in deploying variable renewable energy. Despite better representation of integration impacts and costs, wind and solar technologies remain competitive with other low-carbon options and climate change mitigation drives the share of variable renewable energy technologies to 53-89% of electricity generation in 2100 across the models [2][3].

ENE researchers have also examined the adoption of sustainable technologies in the transport sector, which is responsible for about a quarter of all energy-related CO_2 emissions. Widespread substitution of conventional vehicles with those powered by low-carbon sources of electricity or hydrogen is seen as essential to limit global warming to 2°C. One critical determinant for this transition will be the consumer preferences for which cars to use.

Again, global energy-economy models fall somewhat short here, as they are limited in their representation of consumer decision-making. To improve the situation, ENE researchers led the first global model comparison exercise to date dedicated exclusively to realistically representing consumer behavior in long-term energy transitions.

Their findings emphasize two key points. First, strategies and policies explicitly targeting consumer attitudes toward alternative fuel vehicles are necessary to drive widespread adoption of these technologies; and second, carbon pricing is needed to ensure that the electricity and hydrogen used to power these vehicles are derived from low-carbon sources [4].

In addition to this work, ENE has taken a leading role in scaling up the International Transport and Energy Modeling Consortium, a group of global transportation modelers and analysts from academia, government, industry, and non-governmental organizations. ENE co-organized the consortium's second workshop in 2016 and preliminary results were presented at UN Climate Change Conference COP22 in Marrakech.

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Why do renewables grow faster in some countries than others?

Germany is often identified as a leader in climate policy with its growth in renewables and ambitious energy transition program. Can Germany's experience be replicated in other countries? Answering this requires an understanding of what facilitated Germany's energy development: was it a political choice, economic factors, or technological developments? In 2016 the IIASA Energy program (ENE) explored these questions by comparing Germany's energy history to Japan's.

Why do some countries actively adopt renewables, while others extend their nuclear programs or expand their use of fossil fuels? Simplistic explanations blame slow progress on "lack of political will" or "lobbying by special interests" and link success of renewables with "good policies" and a "strong environmental culture". But empirical analysis of historic changes in energy systems can identify more tangible factors which influence how energy systems evolve.

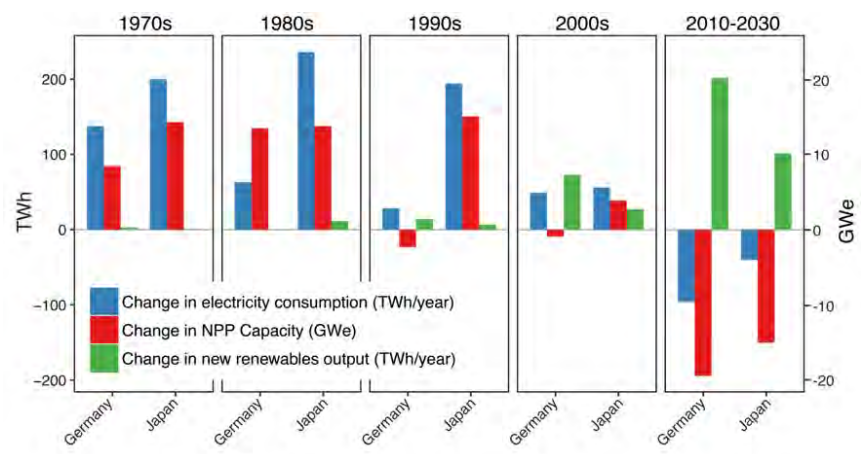
ENE researchers began by comparing Germany and Japan, two countries with similar energy paths in the 1970s and 1980s but very different energy mixes today: Germany is expanding renewables and phasing out nuclear power while Japan lags behind in renewables and relies on nuclear energy. The popular narrative of the "Energiewende" is that Germans rejected nuclear power after Fukushima and expanded renewable energy because of public concern about climate change. In comparison to Germany, Japan is often portrayed as clinging to old ways and unwilling to develop renewables, even after Fukushima [1][2].

ENE research shows that these stories are myths. The difference between Germany and Japan started not after Fukushima, but 20 years earlier when Japan's electricity sector was growing rapidly and it desperately needed new electricity sources, a demand that was not met with scarce fossil fuel reserves. At the same time, Germany was one of the world's biggest coal producers, its electricity consumption stagnated and its energy security improved.

As a result, in the 1990s, Japan was forced to build nuclear power plants, but Germany could do without them, and adopted wind power technology from neighboring Denmark. This adoption happened almost by accident and initially did not significantly impact the country's energy balance, but it did create a large lobby of owners and manufacturers of wind turbines. It was this lobby that, through the Green party and in coalition with pro-coal social democrats, supported Germany's decision to phase out nuclear power in the early 2000s. No such coalition was possible in Japan, which does not have domestic coal, where wind power had not developed, and where the nuclear industry was expanding to satisfy growing demand. By the early 2000s, the nuclear industry in Germany was already on its last legs, while Japan's was flourishing.

What can this history tell us about future energy transitions? The authors argue that these transitions will depend on three groups of factors:

1. Techno-economic: how fast the existing non-renewable resources are depleted, infrastructure ages, and the population and economy grows or declines;
2. Socio-technical: how fast new technologies are diffused from the countries and sectors which introduce them first to other countries and sectors; the flip-side of the same question is how fast the existing socio-technical regimes can fold without causing major social, political or economic disruptions;
3. Political: how actively states pursue their energy goals such as energy independence, what strategies they adopt to facilitate both the growth of new and the decline of old sectors and how successfully the state policies pursuing these goals are captured and distorted by special interests.



Changes in annual electricity consumption, nuclear power (NPP) capacity and non-hydro renewables output by decade, 1970–2010.

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Energy Program

Collaborators

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IIASA by program

Evolution and Ecology Program

Adaptations are key to understanding living systems, especially in these times of global change. In social systems, behaviors adapt through individual and collective learning. In biological systems, genes adapt through evolution under natural and anthropogenic selection pressures. To address these universal challenges in managing the biosphere, the Evolution and Ecology Program devises, analyzes, and calibrates models of complex adaptive systems.

Program website
Scientific recognition
Publications
Staff
Events

Objectives

- Develop new tools for integrating biological, social, and economic dimensions in fisheries assessments.
- Enrich game-theoretical models for common-good management with real-world complexities including bounded rationality, social heterogeneity, cultural dispositions, and institutional incentives.
- Help launch the next generation of dynamic vegetation models.
- Contribute to reconciling polarized conflicts by advancing quantitative stakeholder methods in fisheries management.
- Coordinate an international consortium defining protocols for integrating evolutionary change in annual fisheries assessments.
- Build awareness of dangerous biases in recognizing systemic risks.

Selected highlights

Sustainable fisheries management

Modeling disease eradication

Protecting fisheries from evolutionary change

Resilience of the global seafood trade

Counteracting disease spread over city commuter networks

Modeling love: Understanding the dynamics of human relationships


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Sustainable fisheries management

Both evolutionary and ecological factors interact to influence the growth and size of fish, an IIASA study has shown. Previous work demonstrated that overfishing can lead to evolutionary changes in fish populations, but in a 2016 study the researchers show that a comprehensive perspective on evolutionary and ecological processes is needed in order to understand and manage fisheries sustainably.

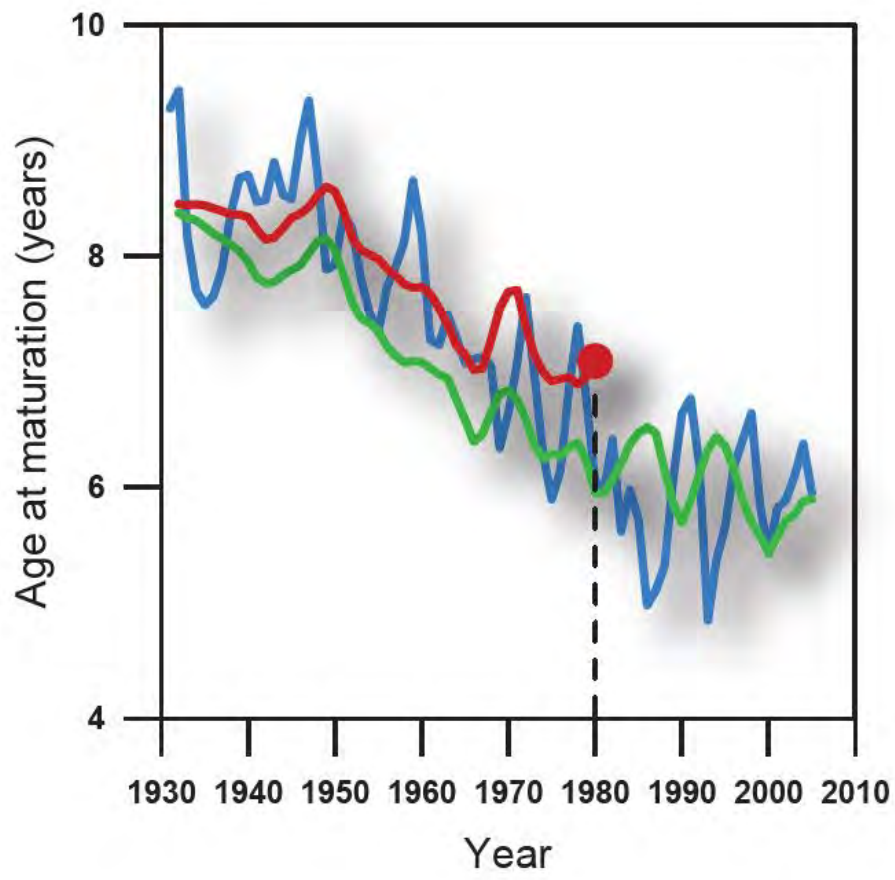
Because fishers usually harvest larger fish, fish populations adapt to the pressure of heavy fishing by evolving to mature earlier and at smaller sizes. This phenomenon is concerning both for the economy and the environment: economically because smaller fish means a smaller catch for fishers, and for the environment because the broader ecosystem impacts of these changes are unclear.

Through a growing body of research, the IIASA Evolution and Ecology Program is elucidating to what extent observed changes in fish populations are caused by non-reversible genetic changes, or evolution, and to what extent the changes are phenotypic, or influenced by the environment rather than genetics. The distinction is crucial for sustainable management, since fisheries-induced genetic changes tend to be slow or impossible to reverse.

In the study, the researchers addressed this question by exploring the relative impact of two factors: density dependence, meaning that when the cod population shrinks through fishing, more food is available, so that fish can grow faster and mature earlier; and life-history evolution, meaning that a trend towards genetic changes causing earlier maturation is induced by the selective harvesting of larger fish.

Using an eco-evolutionary model that could reproduce 74 years of historical data on age and length of maturation in Northeast Arctic cod, they found that a combination of these two factors was likely responsible for the observed changes in fish size. Their carefully calibrated quantitative model also revealed that the cod population might have collapsed around 1980 had it not undergone some life-history evolution that made it more resilient to the high fishing pressures it experienced after World War II.

The study thus shows that ecological and evolutionary dynamics do not work in isolation, but rather as part of a complex system. In order to prevent fisheries collapse, it is important to understand these dynamics and how they interact.



Fisheries-induced evolution causes Northeast Arctic cod to mature at younger ages and smaller sizes. Blue line: Empirical observations. Green line: Eco-evolutionary model predictions. Red line: Non-evolutionary model predictions. The results suggest that without fisheries-induced evolution, high fishing pressures could have caused the stock to go extinct in the 1980s (red circle).

Evolution and Ecology Program

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Further information

- Interview: Are we accidentally genetically engineering the world's fish?
- The evolution of fish and fisheries

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Modeling disease eradication

Diseases evolve in response to treatment, frustrating efforts to eradicate them. In 2016 the IIASA Evolution and Ecology Program explored how evolution, population dynamics, and economic factors interact, providing new insight that could help inform efforts to control diseases like malaria.

Efforts to eradicate a disease are likely to fail if medical professionals only know the target of an eradication campaign, but cannot predict the course for reaching it, according to IIASA research. The 2016 study examined the interplay between disease evolution, human populations, and economic factors to determine how diseases can be controlled, using a new, model-based view of disease eradication.

Despite many efforts to eliminate specific diseases, there have only been two success stories: smallpox and rinderpest. Most of the world's deadly illnesses have survived repeated efforts to eradicate them, resurging in vulnerable populations and in some cases gaining resistance to standard treatment. Malaria, for instance, infected over 200 million people in 2010, killing around 500,000 according to the World Health Organization.

The problem is that it's easy to make progress at the beginning, but in the last stages of eradication, when there are only a few cases, it becomes very difficult to make further progress.

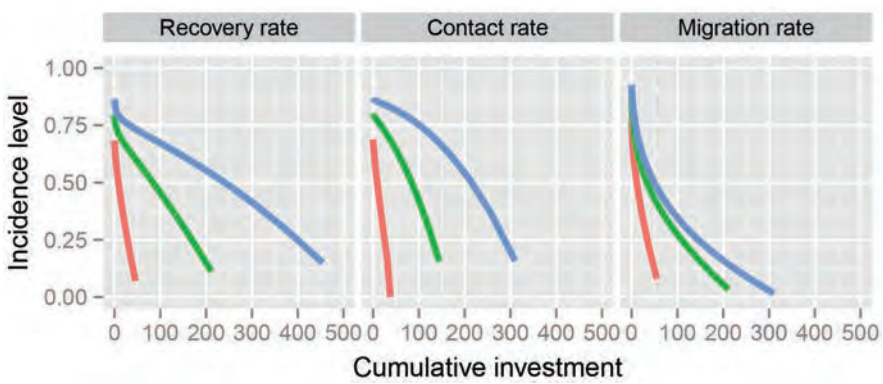
A graph of this process would show a fast decline in the incidence of the disease, which peters out into a long tail that the researchers call an "eradication tail." The reasons for this are multiple. The microbes that cause disease evolve in response to changes in their environment, sometimes gaining resistance to the drugs used against them. Likewise, eradication efforts may target the animal that spreads a disease, such as mosquitoes, which may thus evolve or adapt in response.

Also the way human populations are structured plays a role—since diseases spread between individuals, predicting eradication tails requires mapping a population and links between diseased individuals. And crucially, economic factors contribute as well—if the money for interventions runs out, the disease may come back.

The study examined how much each of these factors affected eradication in a model system. It showed that while all three factors were important, the economic factor played a deciding role in shaping the trajectory of disease eradication.

The researchers found that extending the money and time spent on an eradication campaign can make up for the tendency of evolutionary and population factors to allow a disease to persist. While evolution could allow the disease to develop resistance or become more virulent or deadly, population dynamics could allow the disease to 'hide' in an isolated subset of the population, and spread back to the general population in the future.

Most epidemiology research today has an on-the-ground view of specific disease data. This study shows that a model-based perspective of disease eradication can provide useful information for public health institutions aiming to eradicate diseases.



To reduce an infectious disease's incidence level, health officials need to invest precious resources. As an eradication campaign progresses, these investments have less and less impact, resulting in so-called eradication tails. The shape of these depends on the disease characteristics (colors), as well as on whether the investments help increase the recovery rate of patients from the disease (left panel), decrease the contact rate among healthy and infected patients (middle panel), or restrict the mobility of patients (right panel).

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Protecting fisheries from evolutionary change

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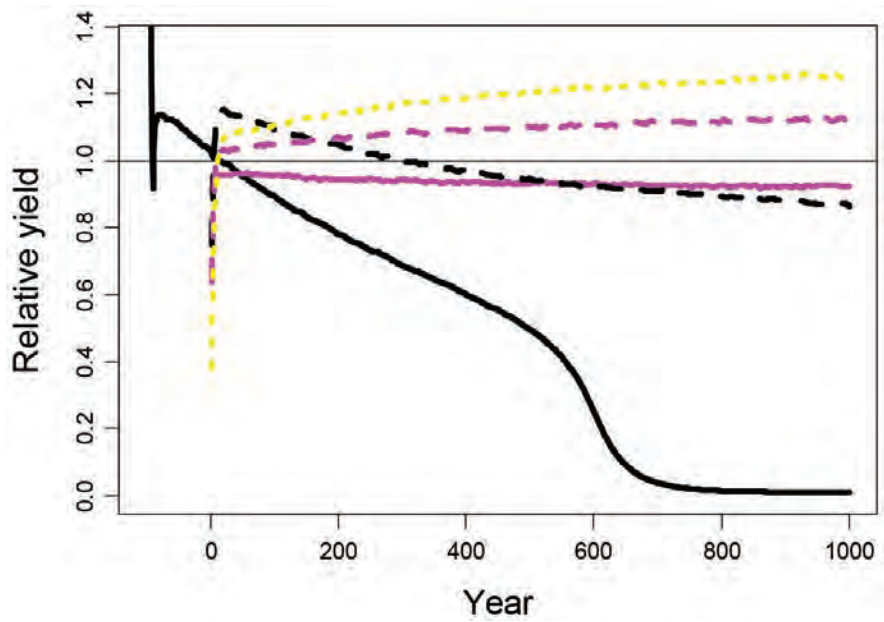
Evolutionary changes could lead to reduced fishery yields. In 2016 researchers from the IIASA Evolution and Ecology Program showed how alternative management practices could mitigate the problem in a key North Sea fishery.

North Sea plaice is the most commonly fished flatfish in Europe, with landings of around 120,000 metric tons per year. But if current trends continue, evolutionary changes will lead to a decreased catch of this important food source.

Previous research has shown that fishing can cause evolutionary changes in fish populations, with impacts such as earlier maturation or smaller size. This is because removing the largest fish from a population also removes them from the gene pool. Over a few generations, this can lead to smaller fish that mature at an earlier age, which translates into a smaller catch for fishers.

These impacts have already been observed in the plaice fishery. In addition to reducing the amount of fish available for catch, researchers surmise that such changes will be difficult or slow to revert and can make fish populations more vulnerable to collapse.



Fishing North Sea plaice causes it to evolve, changing how the fishery's yield develops.
Black continuous line: The current fishing practice causes long-term yield erosion.
Black dashed line: Reducing the fishing pressure on all fish to one half still causes long-term yield erosion, albeit at a slower pace.
Magenta continuous line: Reducing the fishing pressure on large fish to one half stops the yield erosion.
Magenta dashed line: Reducing the fishing pressure on medium-sized fish to one half and on large fish to one quarter causes a long-term increase in yield.
Yellow dotted line: The best yield increase is achieved by protecting small fish combined with reducing the fishing pressure on medium-sized fish to one quarter and on large fish to one eighth.

This study is the first to combine the quantification of evolutionary impacts for a specific stock with tailored projections for different management scenarios. To conduct the study, the team applied models using the Evolutionary Impact Assessment framework, developed by IIASA researchers and their colleagues to provide fisheries managers with a set of tools to understand the potential impacts of evolutionary change on fisheries.

Underscoring cautionary findings reported in earlier IIASA studies, for example on Northeast Arctic cod fished north of Norway and on northern cod caught east of Canada, the new research draws attention to the accumulating 'Darwinian debt' current fishing practices are incurring. In other words, each year these practices go on is likely to require many more years of different fishing practices before the exploited stocks recover from the evolutionary changes.

Management practices that target fish differently from current practices could help mitigate the problem and maintain a higher sustainable catch, the study shows. By shifting fishing pressures from the largest fish to intermediately sized fish, fisheries managers could ensure that the population stays stable from an evolutionary perspective.

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Evolution and Ecology Program

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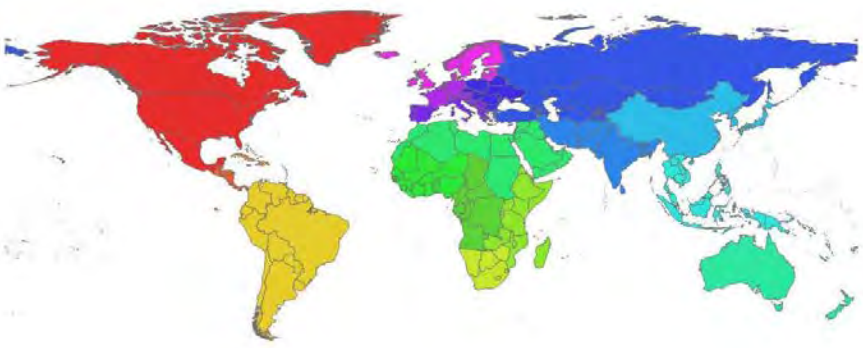
Resilience of the global seafood trade

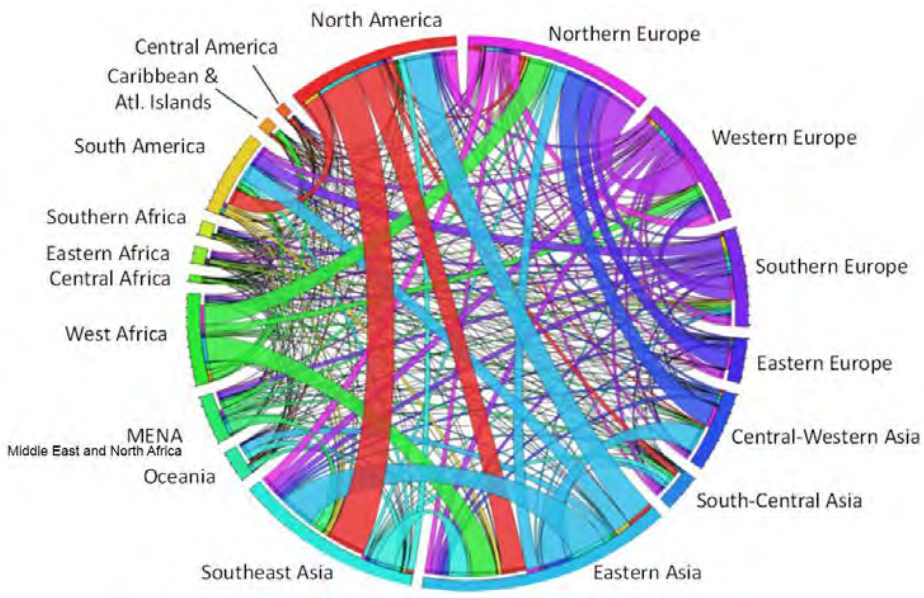
Today's supply chains extend across the world and trade is a truly global phenomenon. It is therefore an issue of national security for every country to ensure the sustainability of their exports and imports. In a 2016 study IIASA researchers examined the resilience of the seafood trade in the face of global change.

Seafood plays an important role in food security, making up nearly 20% of animal protein consumption around the world. At the same time, seafood supplies are vulnerable to natural disasters, fishery collapses, policy changes, and price spikes in fossil fuels.

To examine how seafood trade might be affected by such shocks, researchers from the IIASA Advanced Systems Analysis and Evolution and Ecology programs developed a shock-propagation global trade network model. The results show that Central and West Africa are the most vulnerable to shocks. In addition, if such an event did occur, richer regions might be more willing to prioritize their domestic consumption, which would pass on the shock to other regions in the trade network. If this is taken into account in the model, the researchers found, Central and West Africa are even more at risk.



These findings suggest that countries can reduce their overall vulnerability to shocks by reducing reliance on imports and diversifying food sources. As international seafood trade grows, identifying these types of potential risks and vulnerabilities is important to build a more resilient food system [1].



Global seafood trade among world regions. A band's width represents the traded biomass and a band's color represents the importing region. The new study assesses the vulnerability of world regions to supply shocks in this trade network.

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Counteracting disease spread over city commuter networks

To fight the outbreak and spread of disease across public transport networks, city health officials should target the largest station, as preventative measures there are likely to be substantially more effective than at any of the smaller stations, IIASA work has shown. For the study researchers developed a new method for identifying the stations with the highest benefits in fighting disease spread, and tested it on the Tokyo public transport system.

Public transport networks in large cities are the perfect way for a disease to spread. The confined spaces, the high numbers of people passing through—especially during the daily commute—mean that a virulent disease could make its way across the city in even a few hours.

To face this challenge, health officials need to design countermeasures that fight disease spread while remaining cost effective. A promising strategy, research shows, is to target the hubs of the transport network, such as particularly busy stations. A study by the IIASA Evolution and Ecology Program uses innovative network analysis to show how such hubs can best be identified.

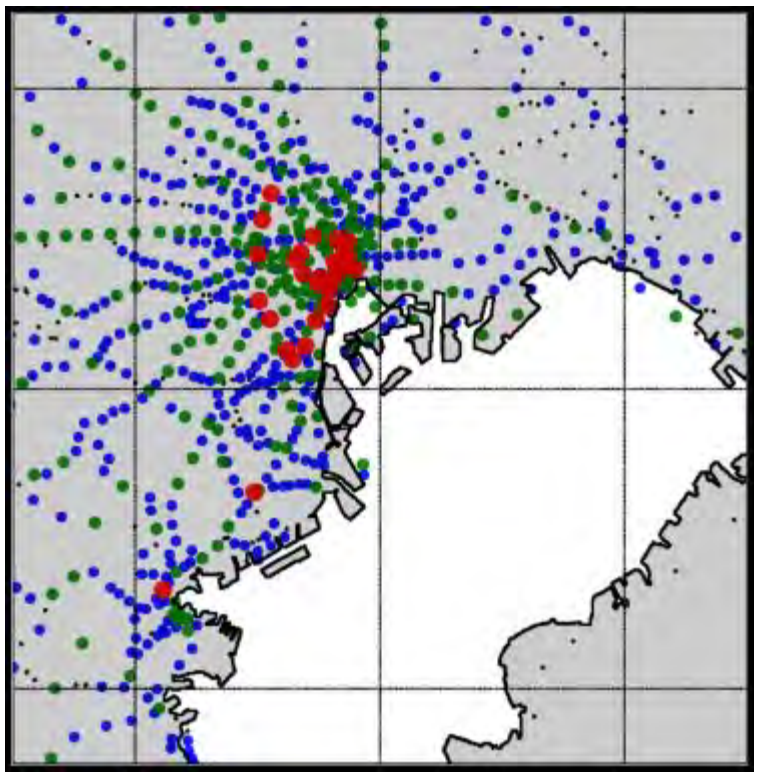
Using Tokyo as a test case, the team developed a new type of "network centrality measure," which quantifies the relative importance—in terms of disease spread—of each location in the network.

The results show that the impact of taking countermeasures at the largest station is more than 1,000 times more effective in stopping disease spread than at the second largest station, even though the number of people passing through is only around 1.5 times larger. On top of this, the effect of countermeasures at other stations is strongly dependent on the number of commuters at the largest station.

Providing vital information to city health officials around the world, this study is among the first to show that only the largest hubs play such an extraordinary role.

The researchers also found the stations that are important for preventing an outbreak of infection in the population are not necessarily the same as those that are important for reducing the number of people infected.

This means that health officials must design different strategies for before a disease is identified and after it has begun to spread.



Commuter network of the Tokyo Metropolitan Area. Each circle corresponds to a station of the public transportation network, with colors indicating daily commuter numbers (black: < 1,000; blue: < 10,000; green: < 100,000; red: > 100,000). The study helps select stations offering the highest returns on disease-fighting investments.

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Evolution and Ecology Program

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Modeling love: Understanding the dynamics of human relationships

Is it possible to predict how love affairs will develop using mathematical models? According to the book *Modeling Love Dynamics* by researchers from the IIASA Evolution and Ecology Program and colleagues, the simple answer is yes. The message from the research is that prediction is possible, if the way each individual reacts to the love and appeal of their partner can be described in formulas.

Consider a standard love story, which develops like those described in a classic Hollywood movie such as "Titanic." This story can be modeled by considering appealing individuals who increase their own love as their partner's increases—so called secure individuals. Starting from the state of indifference, where the individuals are at their first encounter, their feelings continuously grow and tend toward a positive plateau.

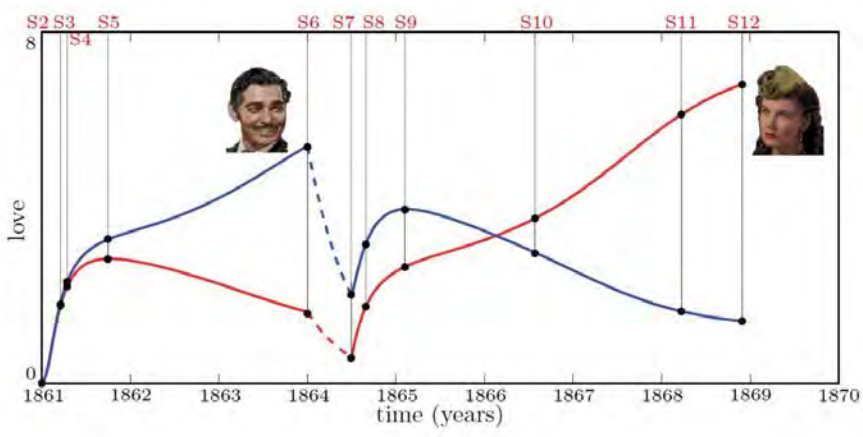
Love stories become more intriguing when one individual is not particularly appealing, if not repellant, as in the fairy tale "Beauty and The Beast." In these cases, there is a second romantic regime, which can lead to marital dissolution in the long run. In order to avoid that trap, people who are not very charming do all they can to look more attractive to the partner at first. After a while, the bluffing can stop, because the couple has entered the safe basin of attraction.

Not all individuals are secure. Indeed, some people react less strongly when the love of their partner exceeds a certain threshold. These individuals, often very keen on flirtation, are less capable of becoming one with their partner. The model shows that couples composed of insecure individuals tend, with almost no exception, toward an unbalanced romantic regime in which the most insecure is only marginally involved and is therefore prone to break up the relationship at the first opportunity. This is illustrated by the characters Scarlett O'Hara and Rhett Butler in the famous film "Gone with the Wind".

Mathematical models can also be used to interpret more complex romantic behaviors. Take the case of "biased" individuals who overestimate the appeal of their partners when they are more in love with them. Interestingly, if insecurity is also present, biased couples can have romantic regimes characterized by recurrent ups and downs. In other words, bias and insecurity is an explosive mix that makes for a turbulent relationship.

The second part of the book focuses on the effects of the social environment. In this context, the researchers analyze the 20-year relationship between the famous Italian poet Francis Petrarch and a woman known only as "Laura," showing that poetic inspiration is an important destabilizing factor, responsible for transforming a quiet relationship into a turbulent one.

Finally, the team studied triangular relationships, with emphasis on the effects of conflict and jealousy. In these cases, the dynamics of feelings can be very wild, up to the point of being chaotic and, hence, unpredictable. When this occurs, the life of the couple becomes unsustainable, because painful periods of crisis can start at virtually any moment: a heavy permanent stress.



Example of how complex human relationships can be understood as dynamical systems. The illustration refers to "Gone with the Wind", one of the most popular films of all time. The red and blue lines, respectively, show the time evolution of Scarlett O'Hara's and Rhett Butler's involvements during their love story, as predicted by the mathematical model by Rinaldi et al. [1].

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Evolution and Ecology Program

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Risk and Resilience Program

The major risks facing the world—from extreme events, to food and water security, to climate change—are complex, systemic, and far-reaching. Building on a history of ground-breaking research, the Risk and Resilience Program is well positioned to take an interdisciplinary, systems perspective on risk policy problems. The program aims to help transform the way societies manage risks while confronting the global trends amplifying them. There is also a strong emphasis on enhancing the resilience of vulnerable communities, countries, and regions.

Program website
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Objectives

- Develop the next generation of the Risk and Resilience Program's Catastrophe Simulation Model to incorporate interdependent risks and longer-term scenarios, with applications to flood resilience, the Loss and Damage Mechanism, UN Sustainable Development Goals, and other risk topics.
- As part of the Flood Resilience Alliance, co-develop innovative resilience measurements and management methods and tools.
- Expand into new areas of risk research exploring contributions to the energy-water-nexus and how to achieve the Sustainable Development Goals.
- Further develop and apply the Risk and Resilience Program's participatory process design incorporating the heterogeneity of stakeholder views, multi-criteria analysis, and social media applications.
- Initiate and develop an extensive research network informing policymakers on how to address the loss and damage associated with the impacts of climate change, particularly in vulnerable developing countries.
- Establish a broad, capacity-building platform on disaster risk management and resilience to serve relevant institutions in IIASA member countries.

Selected highlights

Disaster forensics: Detecting best practice

Untangling uncertainty for disaster risk projections

Negotiating climate loss and damage

Participatory mapping to enhance disaster resilience

Rethinking expert engagement in participatory processes

Can insurance effectively support climate resilience?

Disaster forensics: Detecting best practice

Disaster forensics—learning about the successes and failures in disaster risk management and resilience—will be vital if we are to adapt to our changing world. The IIASA Risk and Resilience Program have helped develop a new methodology, known as the post-event review capability (PERC) approach, for systematically analyzing disaster events and identifying actionable recommendations.

The risk of disasters such as floods is on the rise, and there is an urgent need to improve our understanding and response to these events. The PERC methodology—developed by IIASA, the Zurich Insurance Group, and the Institute for Social and Environmental Transition-International—systematically and holistically analyzes disasters, helping those in the field to learn from successes and failures in disaster risk management and resilience. It also helps to uncover the underlying drivers of increasing risk. Unique in the disaster forensics field because of its policy-oriented and holistic focus, the PERC methodology is designed to generate objective, politically neutral insights and actionable recommendations in a policy-relevant timeframe following a disaster event.

The PERC approach has been applied seven times to date: for the floods in southern Germany in 2016; the floods in Columbia and Charleston, USA in 2015; the floods in Benevento, Italy in 2015; flooding and storm damage from storm Desmond in the UK in 2015; the floods in Algarve, Portugal in 2015; the floods in Guelmim and Sidi Ifni, Morocco in 2014; the floods in Karnali, Nepal in 2014; the floods in Emmental, Switzerland 2014; the Balkan floods (Bosnia and Herzegovina, Serbia and Croatia) in 2014; storm Xaver in the UK in 2013; the Boulder floods in the USA 2013; the Central European floods in 2013 (Austria, Czech Republic, Germany, and Switzerland).

By carrying out a meta-analysis of these different case studies, IIASA researchers demonstrated that policymakers and practitioners in disaster risk management face strikingly similar challenges across the globe, despite their different contexts. This indicates that there is good potential for mutual learning.

The case studies also highlight the importance of integrated risk reduction strategies, which combine risk reduction (e.g., building dikes), preparedness (e.g., early warning systems), and risk financing (e.g., insurance).

IIASA researchers are now encouraging others in disaster risk management to use the PERC approach—which is freely available to all—and to contribute to building a repository of learning for disaster risk management and resilience.

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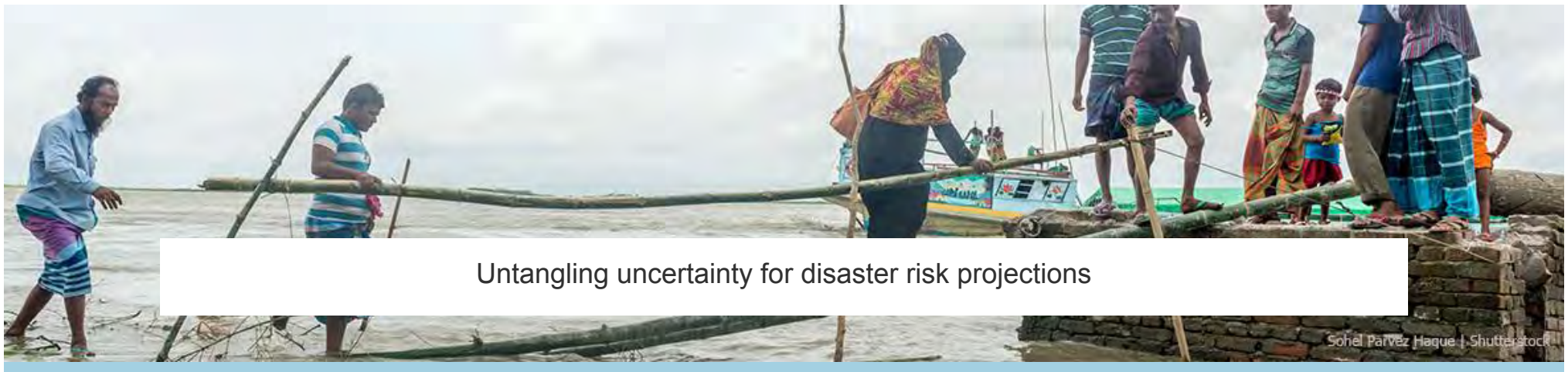
Risk and Resilience Program

Collaborators

- Zurich Insurance Group
- Institute for Social and Environmental Transition-International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Untangling uncertainty for disaster risk projections

When assessing and understanding the risks that accompany disasters, both researchers and policymakers must grapple with uncertainties. In a study of extreme flood risk in Bangladesh, IIASA researchers show that socioeconomic uncertainty is more important to risk predictions in the short term, but climate uncertainty becomes more relevant in the longer term.

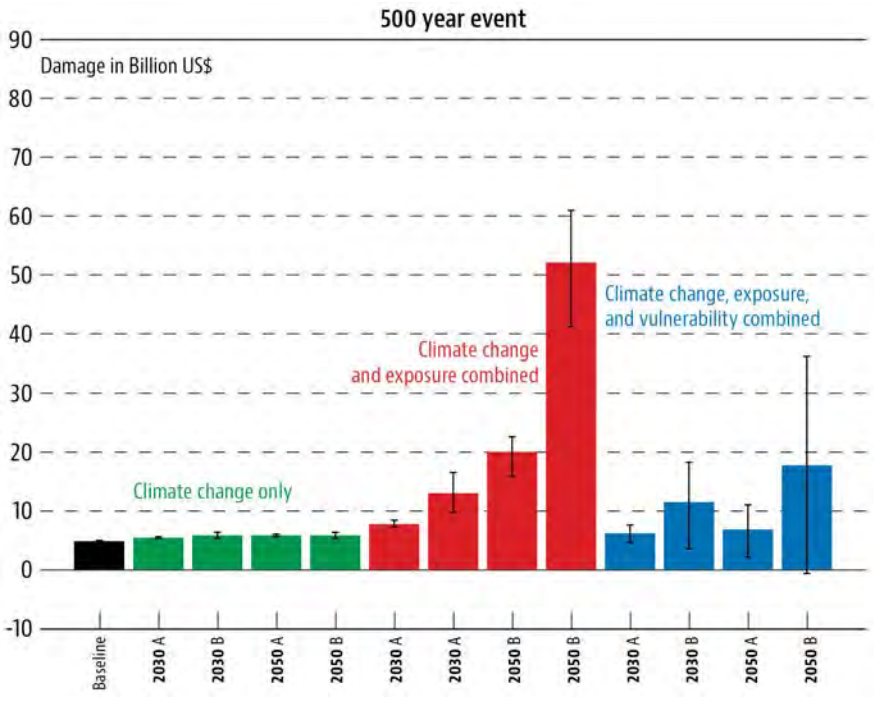
Few studies dissect the drivers of long-term risk, however this work from the IIASA Risk and Resilience Program fills this gap by using a case study of extreme flood risk in Bangladesh. The study examines how sources of uncertainty in the scenarios and models used could affect estimates of future loss caused by extreme events.

There are three main drivers of extreme risks: climate change, exposure, and vulnerability, and they affect risk in different ways. Exposure, for example, describes the assets such as houses or infrastructure that are at risk. The greater the number of houses on a flood plain the greater the exposure. Socioeconomic development can affect exposure in particular because if more houses are built there is also a higher possibility that more will get damaged, irrespective of climate change or vulnerability changes.

By examining different assumptions regarding climate, exposure, and vulnerability the researchers showed that scenario uncertainty regarding socioeconomic development seems to contribute the most to the variability in results.

While socioeconomic uncertainty is more dominant than climate change uncertainty, the longer the timescale considered, the larger the relative contribution of climate uncertainty to the estimated economic loss. The figure shows the losses for a 500 year event: for 2030 and 2050, under two climate scenarios A and B, looking at either climate change impact only, climate change and exposure impacts combined, or the full combination of climate change, exposure, and vulnerability combined.

This shows that while climate change and increases in housing and infrastructure assets may cause devastating impacts in future extreme events (see column 2050 B in the 'climate change and exposure combined' category) reducing in vulnerability can also significantly decrease losses (see column 2050 B in the 'climate change, exposure, and vulnerability combined' category).



Mean and standard deviation of loss estimate under alternative scenarios for Bangladesh flood risk (in billion US$). Baseline is the current risk.

A systems perspective taking all three drivers into account—climate change, exposure, and vulnerability—is needed to inform policy targets and implementation according to different timescales. The research has important implications for decreasing future extreme risks at national levels. Freeing countries from the burden of these losses will also help them to achieve the Sustainable Development Goals.

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Risk and Resilience Program


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Negotiating climate loss and damage

The Paris climate agreement included groundbreaking text on the need to identify risks beyond adaptation and support the victims of climate-related loss and damage—but how exactly it will work remains unclear. An IIASA paper has laid out a framework to point a way forward in these complex negotiations as well as making suggestions for the next steps in research.

It is widely agreed that many countries will need assistance in responding to climate change—indeed some are already suffering sever impacts—yet there has been a contentious debate between vulnerable countries and developed nations about the extent of such assistance and the form that it should take.

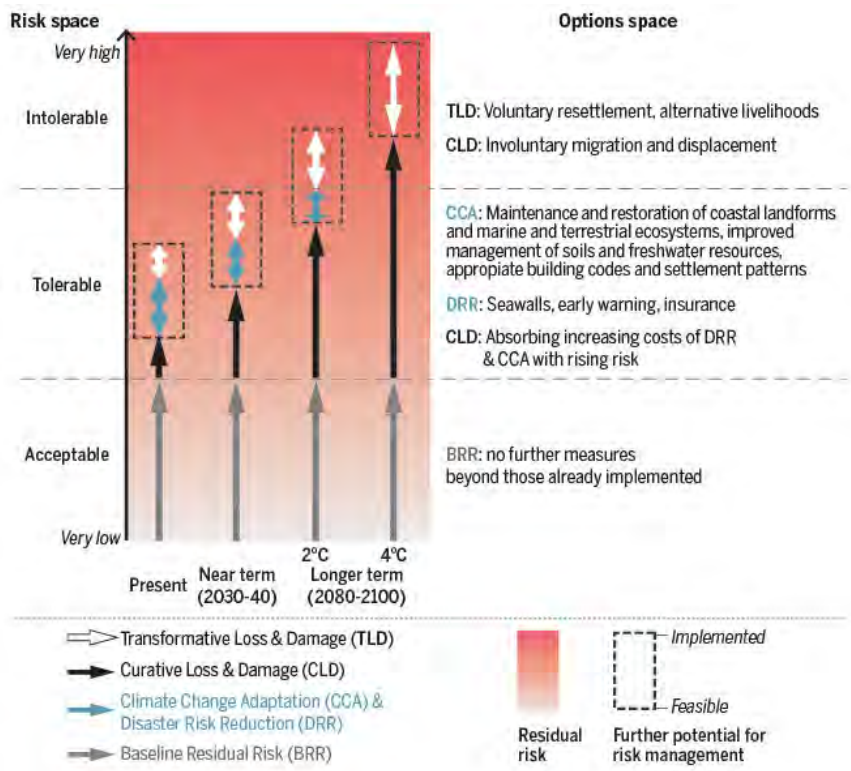
In a paper published in the journal *Science*, researchers from the IIASA Risk and Resilience Program lay out a framework for loss and damage in terms of supporting measures that can help vulnerable people survive, adapt, and even become more resilient in the face of irreversible climate change impacts.

The researchers identify two sets of options where developed and developing countries could agree on international support for coping with loss and damage in addition to support for climate adaptation.

The first set of options refers to support for "curative" measures, which deal with unavoided and unavoidable risks. An example of such measures would be seawalls, needed to cope with rising sea levels caused by climate change. At high levels of warming, impacts become unavoidable, and people may be forced to migrate, for which international legal protection is essential.

The second set of options refers to the concept of transformative risk management—that means building resilience against climate-related impacts while also realizing that people will need support to learn new skills and develop new livelihoods, or even voluntarily migrate to new homes. Transformative risk management goes beyond traditional risk management to enhancing people's resilience more broadly.

In terms of future research, the study concludes that three lines of analysis are of particular importance: (i) ensuring that assessment of climate-related risk is comprehensive; (ii) taking social-science perspective on risk (iii) examining distributive and compensatory justice with regard to burden sharing.



Climate risk management options for small island states. The risk and policy space for Loss and Damage as applied to risks from sea level rise in small island states. The scenarios identify classes of curative measures for unavoided and unavoidable impacts of sea level rise and transformative measures for avoiding and managing increasingly intolerable risks.

IIASA by program

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Further information

Informing action on a historic climate agreement

Risk and Resilience Program

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- Rachel James, University of Oxford, UK
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Participatory mapping to enhance disaster resilience

To fill critical knowledge gaps in local flood risk information, IIASA has collaborated with practitioners to engage communities in a participatory process to map risk, resources, and capacities in flood-prone areas in Nepal and Peru. The new digital maps contain more information, are more accurate, and are easier to update and share than conventional flood risk maps.

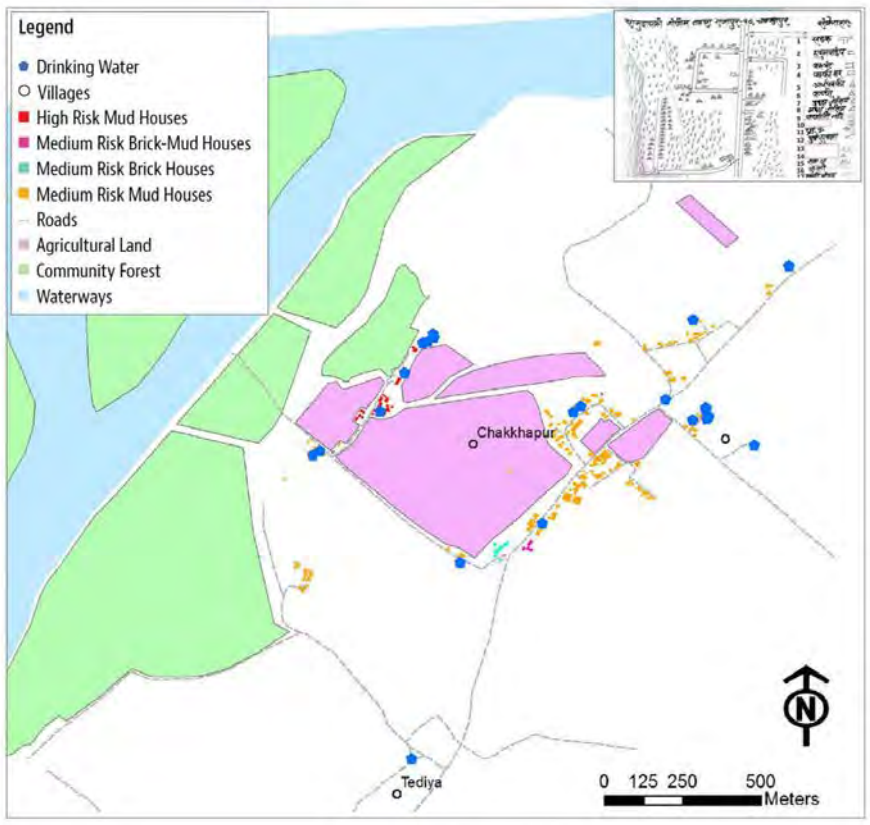
Floods have the largest negative impact of all natural hazards, with about 1.5 billion people worldwide affected since 2000. Reducing risk in flood-prone areas requires a clear understanding of flood risk on the ground. Knowledge of "all dimensions of vulnerability, capacity, exposure of persons and assets, hazard characteristics, and the environment" [1] is needed to inform policies and practices across all stages of the disaster risk management cycle: from pre-disaster risk assessment, to risk prevention and mitigation, to preparedness and effective response.

Critical knowledge gaps seriously hinder efforts to build flood resilience, especially in disaster-prone developing countries. Moreover, information gaps are most serious at local levels, especially in terms of spatial information on risk, resources, and capacities of communities. The recommendation of the Sendai Framework for Disaster Risk Reduction is "to develop, periodically update and disseminate, as appropriate, location-based disaster risk information, including risk maps, to decision makers, the general public and communities at risk of exposure to disaster in an appropriate format by using, as applicable, geospatial information technology" [1].

There is great potential for new technologies to support flood resilience. In addition to existing expert-based data collection and analysis, direct input from communities and citizens across the globe may also be used to monitor, validate, and reduce flood risk. New technologies have already been proven to effectively aid in humanitarian response and recovery. However, while technology is increasingly used to collect information on exposure, efforts directed towards assessing and monitoring hazards and vulnerability remain limited. Hazard model validation and social vulnerability assessments also deserve particular attention.

For this work, researchers from the IIASA Risk and Resilience and Ecosystems Services and Management Programs developed an approach that combines community-based participatory mapping processes with emerging internet-based digital mapping techniques [2]. In collaboration with Practical Action (a UK non-profit organization) and local professionals, IIASA researchers demonstrated the value and potential of this participatory and collaborative digital mapping approach in the flood-prone lower Karnali River basin in western Nepal.

The new digital community maps are richer in content, more accurate, and easier to update and share than those produced using conventional vulnerability and capacity assessments. The process engaged a wide range of stakeholders to generate geographic information on resources, capacities and flood risks of pilot communities based on their local needs. This approach, as an inclusive form of risk knowledge generation, can make important contribution to the understanding of disaster risk and therefore help enhance disaster resilience. The team continues to work with collaborators to map more communities in western Nepal and mountainous Peru [3].



Participatory mapping

Conventional hand-drawn community risk map, capacity map, and social map versus digital community map produced via a participatory and collaborative mapping approach.

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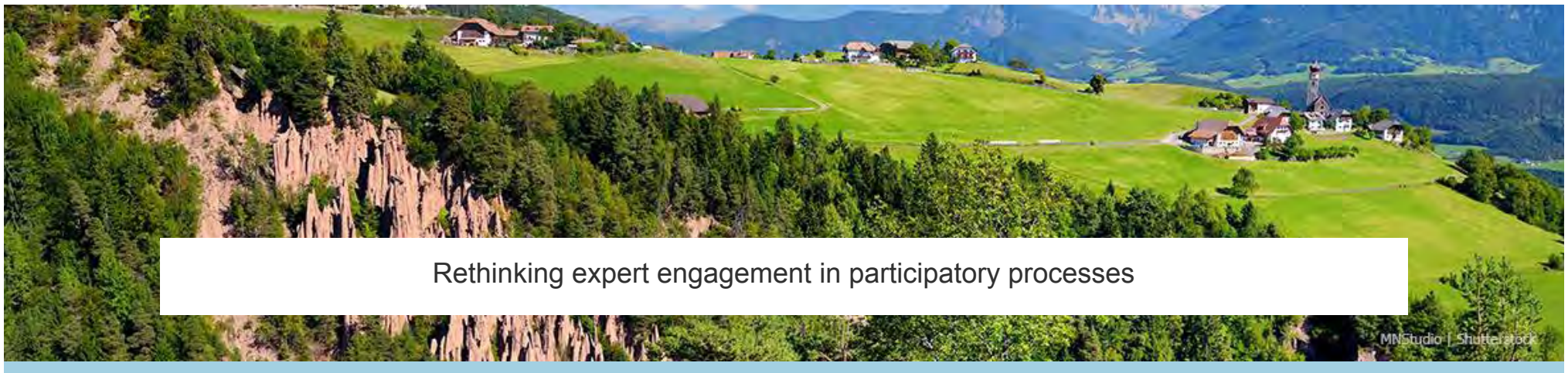
Risk and Resilience Program

Collaborators

- Practical Action and Practical Action Consulting, UK and Nepal.
- International Federation of Red Cross and Red Crescent Societies
- Kathmandu Living Labs, Nepal



Rethinking expert engagement in participatory processes

IIASA scientists have developed and tested a new way for disaster-risk experts to engage in participatory and deliberative processes, differing significantly from their traditional role of simply providing policymakers with technical solutions. In the new method landslide experts interactively developed risk protection options that corresponded to the different perspectives of the stakeholders. As a result, experts and stakeholders were able to co-produce useable knowledge.

The unique participatory process, developed by the IIASA Risk and Resilience Program, was designed to reduce landslide risk in the highly exposed Italian town of Nocera Inferiore. The process, along with the complementary scientific risk analyses and decision tools, was presented in a 2016 special issue of the journal *Natural Hazards* entitled *Rethinking participatory processes: the case of landslide risk in Nocera Inferiore* [1].

The three-year participatory process, described in [2], was carried out in a town where public opposition to an expert-proposed landslide risk mitigation project had resulted in a stalemate. Under the new approach, citizens and experts co-produced landslide risk mitigation options. The main difference in this case, compared with other analytic-deliberative processes, was its explicit elicitation of multiple stakeholder perspectives on the nature of the problem and its solution.

The process began, as described in [3], with experts identifying three distinctly different discourses, reflecting the varying views of the community: “safety first” with emphasis on a mix of active and passive structural measures; “careful stewardship of the mountain” requiring (mainly) natural measures like a belt of trees to actively stop the landslide, and “rational choice” with emphasis on the opportunity costs of all measures and the need for informed individual choice, for instance, in the construction of homes.

The expert support, which also included quantitative risk analysis and cost-benefit analysis, took these different stakeholder perspectives into account in the design of policy options. A final unique feature of the process was the aim of compromise rather than consensus. Instead of working towards a full agreement on the problem and its “best” solution, the participants forged a compromise, recognizing that there are multiple ways to view a problem and the “best” solutions.

Experts produced three technical options that reflected these distinct views and at the same time complied with Italian law requiring a high degree of safety in public landslide investments. The measures ranged from structural storage basins that passively block the path of the landslide, rills and forestation that actively prevent landslides, and warning systems that reduce the consequences. The options were discussed and refined by participants and experts in the deliberative process until they adequately reflected the “contested terrain”. This served as the basis for negotiating a compromise. The provision of multiple co-produced policy options enhanced stakeholder deliberation by respecting legitimate differences in values and worldviews.

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Risk and Resilience Program


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Can insurance effectively support climate resilience?

The application of insurance as a mechanism to help vulnerable people adapt to the impacts of climate change is gaining international recognition. In a review and discussion paper IIASA researchers support the idea but warn of potential problems.

In December 2016, negotiators at the Paris climate meeting adopted insurance as an instrument to aid climate adaptation. Earlier in the year, leaders of the Group of Seven (G7) had pledged to bring climate insurance to 400 million uninsured individuals in poor countries by 2020.

In their discussion paper, researchers from the IIASA Risk and Resilience Program welcome these developments, but also lay out the difficulties that policymakers will face in turning the ideas into action. They warn that ill-designed and poorly implemented insurance instruments could fail to reach the goals of negotiators, or worse, prove detrimental to the very people they are intended to protect. While insurance could provide funding to help people in need, the researchers point out several ways that such mechanisms could fail.

First, any new insurance scheme in developing countries needs to overcome difficult challenges, including lack of risk data, limited financial literacy, and weak financial infrastructure. Second, insurance for the poor will only be viable if it is linked to adaptation and risk reduction efforts that reduce the underlying risk factors. Climate-resilient infrastructure, adapted agricultural practices, and early warning systems must be included, otherwise climate insurance will be short-lived and far from cost-effective.

In addition, traditional insurance is an expensive mechanism with high transaction and capital costs, making premiums far higher than expected losses. This suggests that adaptation funds might be better spent on other types of safety net rather than on buying insurance cover from international markets. Insurance will also need high levels of subsidies or other forms of support to render it affordable and to avoid shifting responsibility on to those who are the least responsible for climate change, the least able to shoulder the premiums, and in many cases the least able to reduce their losses.

In order to avoid these problems, IIASA experts argue that policymakers should consider climate insurance as part of a wider adaptation strategy rather than in isolation or as an alternative to adaptation. When installing an insurance scheme, climate change and other factors contributing to the risks need to be taken into account. Also, insurance needs to be coupled with adaptation efforts to deal with these risk factors, otherwise it will be not be sustainable or cost-effective. What is critical for any adaptation or insurance scheme is that there is a good understanding of current and future risks from extreme weather. This is where the experience and tools for risk assessment assembled by risk research will be instrumental.

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Risk and Resilience Program

Collaborators

- Swenja Surminski, London School of Economics and Political Science, UK
- Laurens Bouwer, Deltares, Netherlands

Transitions to New Technologies Program

Technology is central to human development and achieving a sustainable future. The Transitions to New Technologies Program focuses on the core drivers of technological change and on policies for the development and diffusion of fundamentally new technological systems particularly in the areas that are key for global sustainability. International research and collaborative networks, in-house databases, and novel modeling approaches have been developed, allowing the program to address technological change from an interdisciplinary, international perspective, and to inform policy choices for achieving a sustainable future from a systemic technological innovation perspective.

Program website
Scientific recognition
Publications
Staff
Events

Objectives

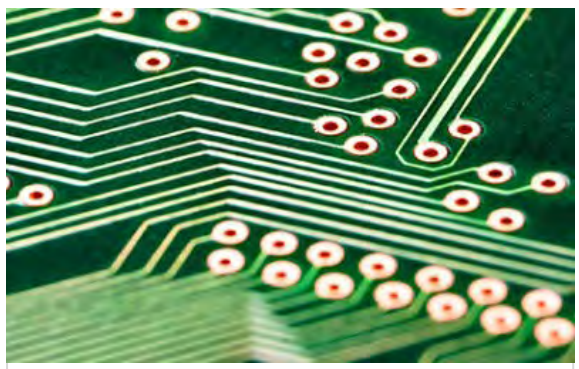
- Develop and maintain databases to assist analysis of technological trends, environmental impacts, and to monitor innovation progress. Develop operational concepts and technology development needs to address critical land-energy-water interactions and potential conflicts using a combined nexus and systems approach to technological innovation.
- Extend systems analysis to technologies identified as critical to resolve conflicts between the UN Sustainable Development Goals (SDGs) via the project The World in 2050, and demonstrate which technology and policy combinations can achieve viable synergies across the all 17 SDGs by 2020.
- Identify key gaps in research and development efforts, niche market creation, and diffusion investments to provide timely advice regarding possible development roadmaps to multilateral and national funding and technology agencies.
- Plan a portfolio of outreach activities based on the program's research which will include policy briefs and stakeholder consultations with policymakers, civil society, private sector, and science and engineering communities.

Selected highlights

The World in 2050

Humanity's shared resources

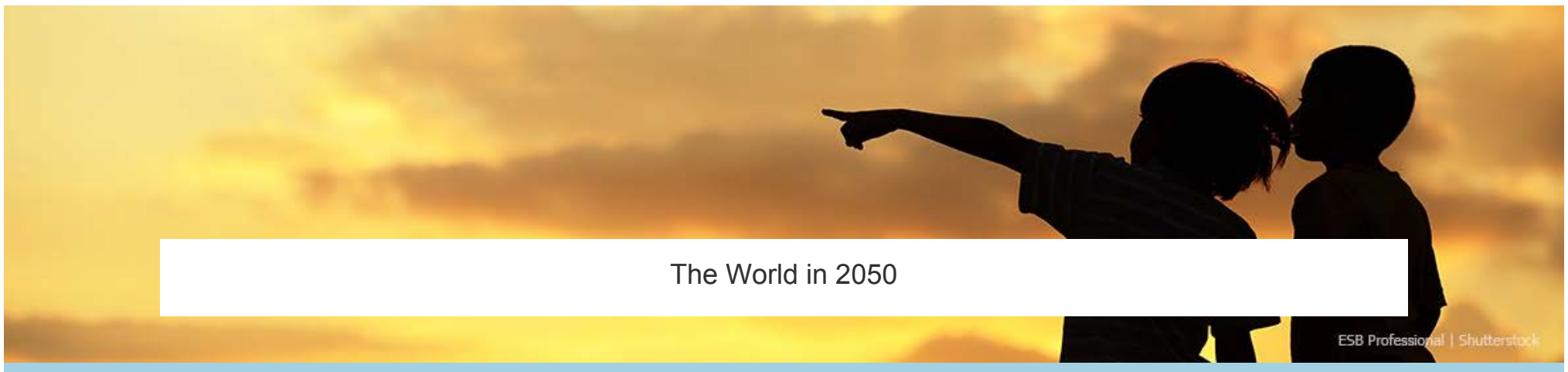
German Advisory Council on Global Change



How to make fast transitions to sustainable pathways

Sustainable transport through agent-based modeling

Online science tools and resources



The World in 2050

Achieving all 17 of the UN Sustainable Development Goals (SDGs) is a mammoth task that will require a strong scientific basis. The World in 2050 (TWI2050) project is aiming to understand how to achieve inclusive economic and social development within planetary boundaries, the benefits of achieving this, as well as the costs of inaction.

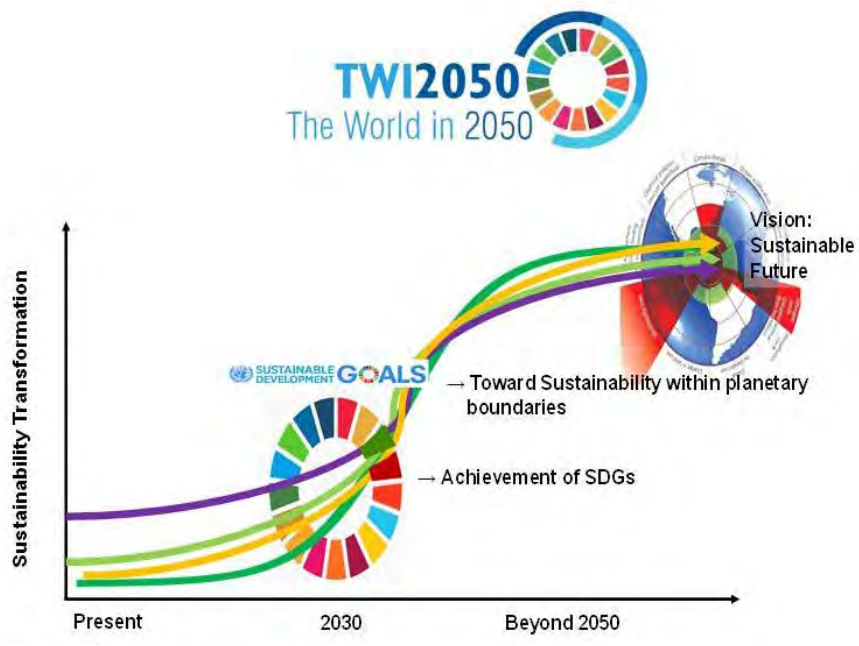
Using a systems approach, TWI2050 will provide science and policy advice for achieving the SDGs in an integrated manner so as to avoid potential conflicts among the 17 goals and reap the benefits of potential synergies.

TWI2050, launched by IIASA, the Sustainable Development Solutions Network, the Stockholm Resilience Center, and the Earth Institute at Columbia University, brings together leading modeling and analytical teams from around the world, including major policy institutions. Under the leadership of IIASA Deputy Director Nebojsa Nakicenovic, researcher in the Transitions to New Technologies Program, the TWI2050 secretariat has been established, with several researchers and a program officer hired in 2016 to join the project.

Technological innovation is of critical importance in achieving the SDGs, and sustainable development beyond 2030 requires a corresponding policy outreach at the highest international level. Recognizing the important contributions of IIASA to all of these factors, the UN Secretary-General appointed Nebojsa Nakicenovic to his special advisory 10-member group to support the Technology Facilitation Mechanism of the SDGs.

The first TWI2050 working meeting, bringing together all major analytical teams, took place in March 2016 at IIASA.

It is vital to understand the connections between the short-term (2030, the timeframe of the SDGs), medium-term (2050, the focus of TWI2050), and the long-term (2100 and beyond, the focus of climate research) dimensions of sustainable development.



Alternative sustainable development pathways that reach all 17 SDGs and the transformation toward sustainability within planetary boundaries beyond 2050. Source: (WBGU 2011).

A framing paper on these links was published in 2016 by Transition to New Technologies researchers, providing critical context for TWI2050 [1]. Important synergies can also be found in the related work of the German Advisory Panel of Global Change (WBGU), on which Neboijsa Nakicenovic served as member from 2010-2016.

References

[1] Nakicenovic N, Rockström J, Gaffney O, & Zimm C (2016). Global Commons in the Anthropocene: World Development on a Stable and Resilient Planet. IIASA Working Paper. IIASA, Laxenburg, Austria: WP-16-019.

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Transitions to New Technologies Program

Funding partners

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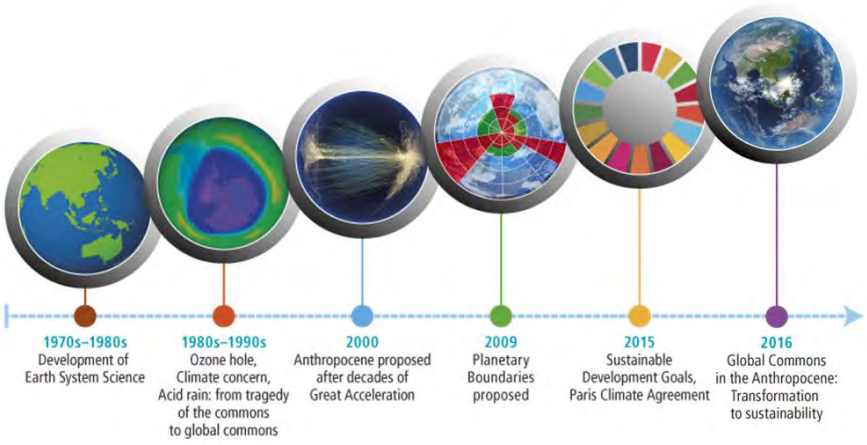
- Stockholm Resilience Center, Sweden Earth Institute
- at Columbia University, USA

For a full list of collaborators, which is being continuously extended see:
www.twi2050.org

Humanity's shared resources

The global commons of the Anthropocene—ranging from rainforests to oceans and glaciers—are essential for the stability and resilience of our planet. Researchers from the Transitions to New Technologies Program and collaborators explored the changing nature of these global commons in the 21st century, in a paper published at the request of the Global Environment Facility (GEF) and the International Union for Conservation of Nature (IUCN).

'Global commons' are resources shared by all on Earth. They include natural resources such as the oceans and the atmosphere, along with human-made phenomena such as cyberspace. Traditional definitions rooted in international law state that to be 'global' the commons must lie outside national jurisdiction.



The Global Commons in the Anthropocene concept builds upon advances in research and in the international environmental and development policy process of the past decades.

But the stability and resilience of the planet are influenced not only by the resources shared among nations. All ecosystems, biomes, and processes that regulate the stability and resilience of the Earth system are common to humanity: they are the new 'global commons of the Anthropocene.' These are both global commons as recognized under international law but also resources within national jurisdictions, such as rainforests, sea ice, mangroves, and biodiversity [1].

In a 2016, researchers from the IIASA Transitions to new Technologies Program published a paper entitled "*Global Commons in the Anthropocene: World Development on a Stable and Resilient Planet*" exploring the changing nature of the global commons in the 21st century. The paper, written in collaboration with the Stockholm Resilience Centre, was requested by the GEF and the IUCN to complement their new initiative *Our Global Commons.*

The paper was launched at a science-policy conference International Dialogue on the Global Commons, convened at the US National Academy of Sciences jointly by GEF and IUCN. The conference kick-started a broader dialogue on the need to reassess the global commons at all scales in light of the growing human pressures on Earth's life-support systems and to renew efforts to develop a roadmap to manage the commons for the benefit of humanity.

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Transitions to New Technologies Program

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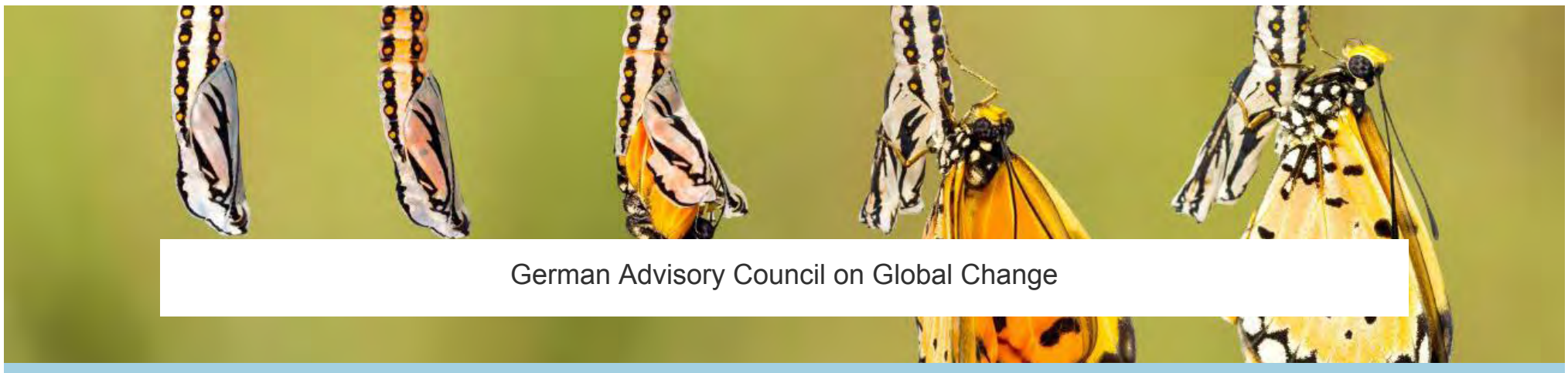
Further collaborators: GEF-Team under lead of GEF CEO and Chairperson Naoko Ishii, IUCN Team under the lead of IUCN Inger Andersen, Earth League Members



German Advisory Council on Global Change

The German Advisory Council on Global Change (WBGU) is a scientific advisory body set up by the German government to provide policy advice. Nebojsa Nakicenovic, IIASA deputy director and researcher in the Transitions to New Technologies Program (TNT), has been one of the nine appointed members since the inception of the WBGU, and completed his second term in 2016.

In 2016, the WBGU published two new reports, both of which were written with substantial TNT input: *Humanity on the move: Unlocking the transformative power of cities* on urbanization, and *Development and justice through transformation: The Four Big 'I's,* addressing the 2030 agenda and the Paris Agreement.

The latter report stresses the role of the G20, a group of twenty major, industrialized, and emerging economies, in advancing the implementation of both agreements, seizing the opportunity of this "great transformation" to sustainability as a unique modernization project that could offer substantial opportunities for economic development. Several researchers from the Transitions to New Technologies Program made significant contributions to the report, including assisting in the analysis of a new transformative energy and climate scenario.

The collaboration between TNT and the WBGU, which concluded in 2016 after six years, exemplifies the policy impact and dissemination strategy followed by IIASA. By collaborating closely with "bridging institutions" such as the WBGU or the Intergovernmental Panel on Climate Change, TNT enjoys a unique access to high-level policymakers for presenting new research results. For instance, the WBGU has had around 10 meetings at the ministerial level, including face-to-face meetings with the German Chancellor Angela Merkel.

Humanity on the move: Unlocking the transformative power of cities, Flagship Report 2016

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Transitions to New Technologies Program

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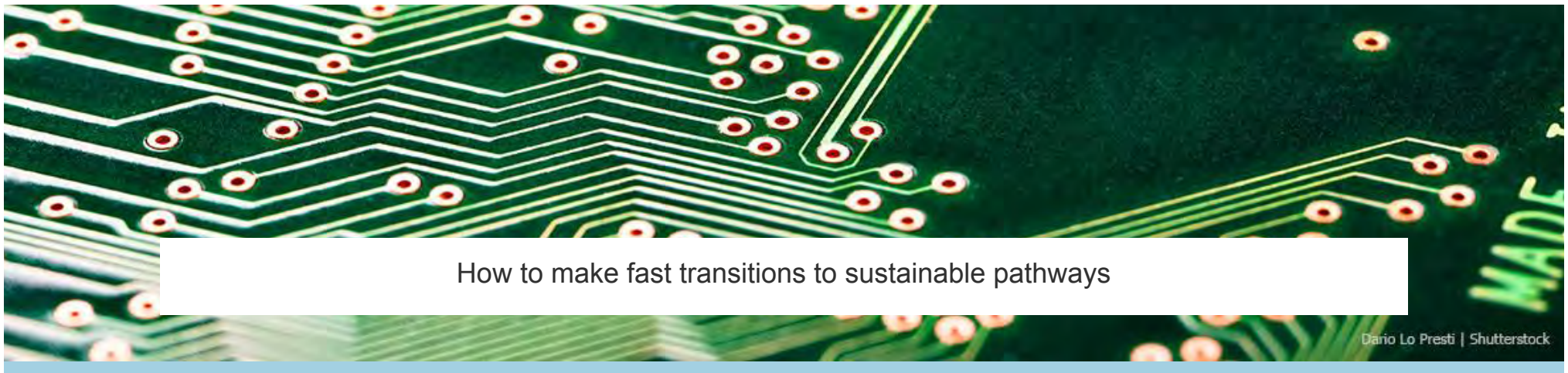
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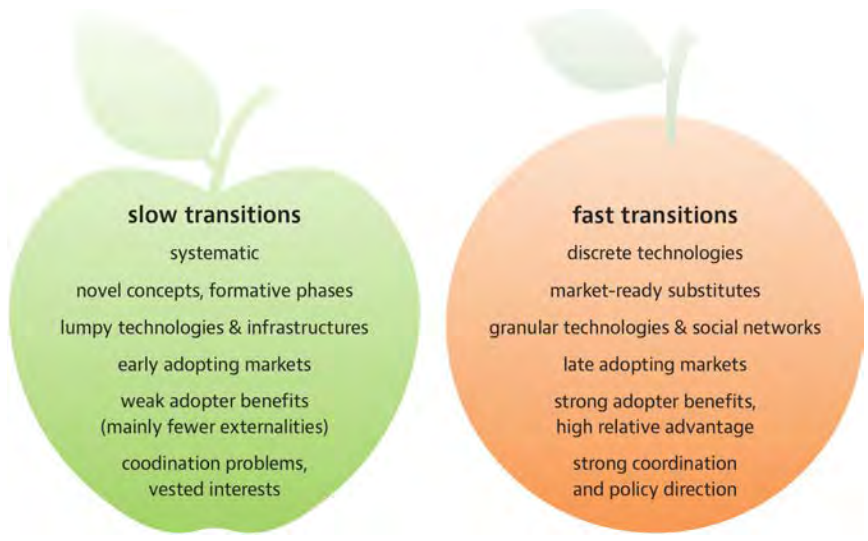
How to make fast transitions to sustainable pathways

Why do some societal and technological transitions happen relatively rapidly, in a decade or two, while others take a century? This question is vital, since achieving the UN Sustainable Development Goals (SDGs) and meeting climate targets will require rapid transitions to sustainability. In a 2016 review paper, the IIASA Transitions to New Technologies Program set out to find the answers.

There is a mismatch between the ambitious timing of the SDGs—which call for major transformational change within a few decades—and the historical evidence, which shows comparable transformative changes have taken up to a century.



A novel taxonomy of determining factors that can explain differences in transition speeds between different transition processes and technological systems ("apples" and "oranges"), which also suggests innovation and policy options for accelerating the much-needed transitions towards sustainability.

The IIASA review paper, published in the journal *Energy Research and Social Science,* was the first to propose a systemic taxonomy of determining factors that can explain why certain transitions happen fast (one to two decades) whereas others proceed slowly (several decades up to a century) [1].

Fast transitions tend to have, among other things, strong coordination and policy direction, along with substantial benefits for adopters. The characteristics of slower transitions include weaker adopter benefits and poor coordination, along with vested interests (see figure for full lists).

The new systemic taxonomy helps to explain differences between "apples" and "oranges", in other words completely different processes and technological systems that cannot be compared without all other things being equal. The findings also provide useful insight for crafting policies and novel technology system configurations to accelerate the multiple social, institutional, and technological transitions needed for the transition to sustainability.

This research integrates a number of novel research streams conducted within the Transitions to New Technologies Program, including work on the development phases of technological innovation; agent-based modeling of technological interrelatedness and complexity; social network and peer effects; and spatial spillover effects in the international diffusion of new technologies [2][3][4].

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Transitions to New Technologies Program

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Sustainable transport through agent-based modeling

People's environmental actions—such as buying an electric car—are profoundly influenced by those around them, with social network interactions and peer effects compensating for a decade's delay in carbon tax introduction and allowing it to be 30% lower. These findings were the results of pioneering agent-based modeling work from the IIASA Transitions to New Technologies Program (TNT).

Individual choices and environmental awareness are an essential part of achieving sustainability; not least because people are more likely to make sustainable choices if those around them do. These so-called peer effects were the focus of work as part of the *Alternative Pathways to Sustainable Development and Climate Stabilization* project, a joint effort between the TNT and Energy (ENE) programs, and colleagues at the Research Institute for Innovative Technologies for the Earth, Japan. After much model development in previous years, the novel agent-based models were sufficiently developed in 2016 to be tested in empirical calibrations with a focus on vehicle choice adoption and transportation systems transitions, which are a traditional weakness of highly aggregated integrated assessment models.

As a calibration exercise, TNT researchers used an agent-based model to replicate the results of a discrete-choice model of the vehicle market in North America, which had been developed by ENE and colleagues. The excellent congruence between these two contrasting modeling approaches enabled the researchers to isolate the effects of social network interactions and peer effects in agent-based modeling scenarios. The model simulations meant they could quantify the market impact of social network and peer effects: by "switching them off," they could determine how much earlier and higher traditional economic incentives such as carbon taxes would have to be to yield comparable market outcomes.

The results are highly instructive for climate policy. Social network and peer effects—which can be enhanced by new information and communication technologies—can compensate for a decade's delay in carbon tax introduction and allow the tax to be 30% lower. Motivating environmentally conscious consumers can therefore be an effective climate policy, especially in cases where early and sufficiently stringent economic climate policy is not possible.

In a second calibration exercise, TNT researchers modified the existing agent-based model of vehicle choice and tested it using real-world data on the vehicle market (conventional and electric) in Shanghai, China. The city was chosen because the electric vehicle market is particularly large and dynamic (rivalling markets such as California, USA, or Norway).

The researchers used historical data for both conventional and electric vehicles and then performed simulations of future market growth under a range of policy scenarios. Currently, economic incentives for electric vehicle purchases in Shanghai are unparalleled, including both federal and local government subsidies, as well as a waiver on a car registration fee that is roughly the price of a medium-sized car.

If these strong economic incentives continue, a market penetration of electric vehicles of 80% by 2040 is possible in the scenarios modeled. Social network and peer effects can compensate, to a degree, for a possible weakening of the substantial (and costly) economic incentives to adopt zero-emission vehicles. Alternatively, continued strong policy incentives could yield a complete transformation to zero-emissions urban mobility based on non-motorized mobility (i.e., walking and cycling), electrified public transport, and electric vehicles.

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Transitions to New Technologies Program

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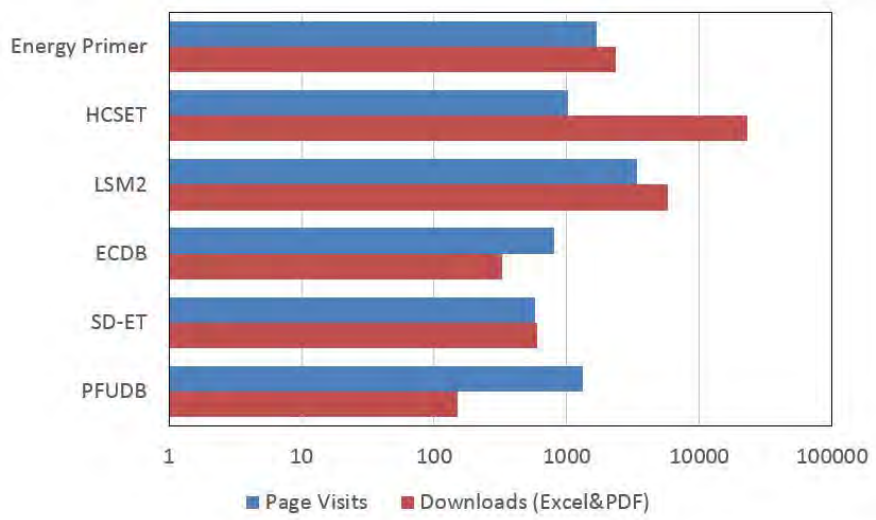
Online science tools and resources

Along with supplying policymakers with decision-support tools, IIASA provides important services to the research community by hosting key databases on issues like climate and population. In 2016, the successful online science tools and resources that are developed jointly by the IIASA Transitions to New Technologies (TNT) and Energy (ENE) programs were expanded and received record number of data requests and downloads.

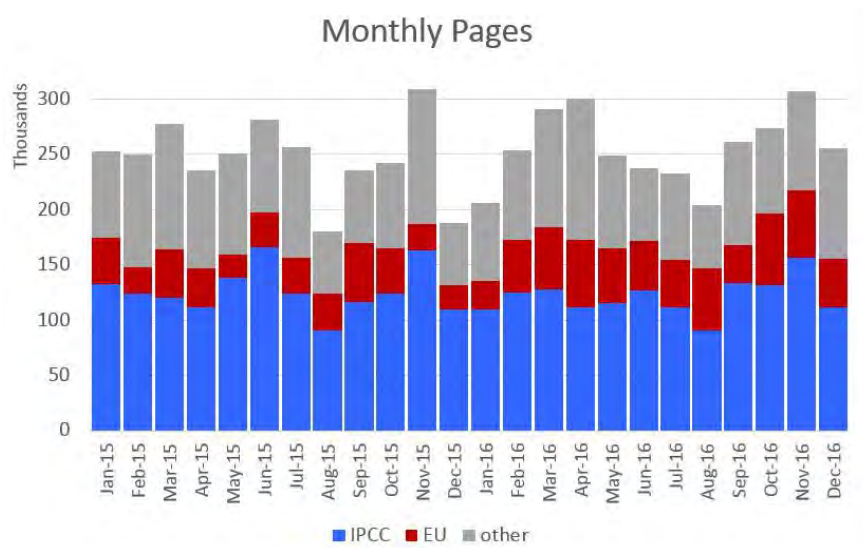
The TNT-ENE community-service database tools have become a hallmark of the IIASA mission of supporting scientific research, documentation, and dissemination. Their reach has grown exceptionally, with page visits and downloads ranging from 10,000 to well over 3 million per year. TNT and ENE scientists have developed a number of web-based solutions for model and scenario inter-comparison projects, including several for the Intergovernmental Panel on Climate Change.



Access statistics in 2016 to TNT's web-based databases, models, and educational resources. Online tool software and data protocols are being jointly developed with ENE.

In total, 24 scenario databases are currently hosted by IIASA and their usage has grown substantially over the years, reaching a new record in 2016.

In order to maintain existing databases and to expand these vital community services, TNT recruited additional staff.



2016 monthly access statistics to web-based databases and other science community-services and tools developed by ENE with contributions by TNT. Altogether some 30 online research tools and databases are offered. The access statistics aggregate them by major scientific constituency and user groups: the Intergovernmental Panel on Climate Change, EU-funded projects, and other databases (including documentation of IIASA in-house research).

Further information

- TNT Databases
- ENE Databases

Transitions to New Technologies Program

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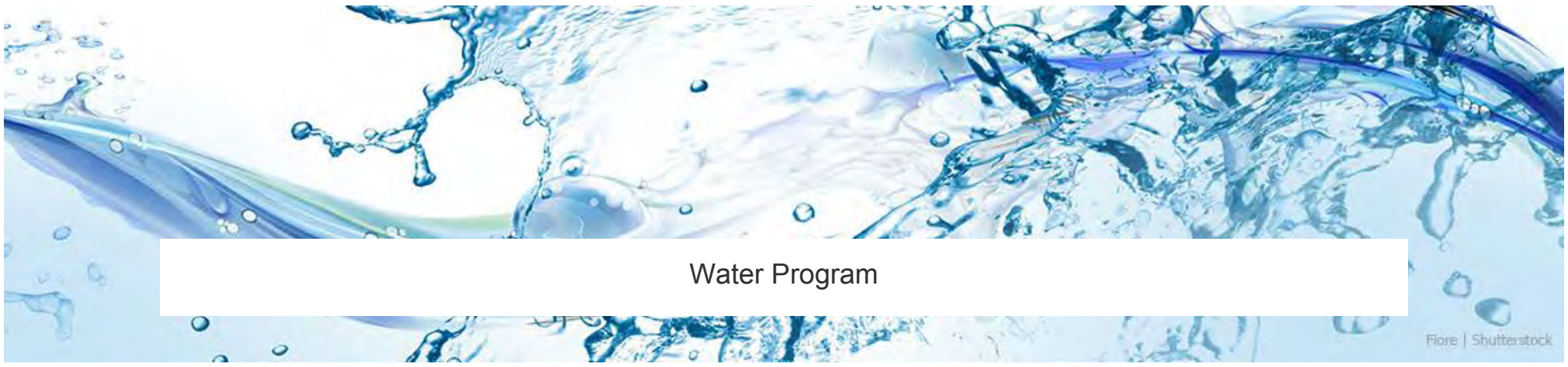


Water Program

The urgent need to address complex and growing water challenges calls for a robust, interdisciplinary approach. The Water Program uses quantified scenarios to explore how different water management policies may affect development in the face of the increasing uncertainty of water challenges. The program provides data, methods, and tools that are consistent across sectors and scales. Together, these drive real improvements in global water security.

Program website
Scientific recognition
Publications
Staff
Events

Objectives

- Develop an integrated nexus approach combining multi-model analysis across sectors and socioeconomic variables, including governance.
- Explore new water scenarios and solutions, based on cutting-edge global and regional modeling, seeking breakthroughs not only in understanding problems but also in developing solutions.
- Enhance knowledge sharing through the development of online databases, decision support tools, and online platforms to help communicate and visualize trade-offs and synergies among options.
- Provide the analytical backbone for a comprehensive report on global water futures and solutions targeted at the World Water Forum in 2018.
- Foster a multi-stakeholder scientific initiative to define water challenges and identify solution options across sectors at multiple scales by holding stakeholder and donor workshops.
- Establish a knowledge hub for science and policy by developing, maintaining, and harmonizing databases on water-related issues.

Selected highlights

Measuring water security with hydro-economic classification

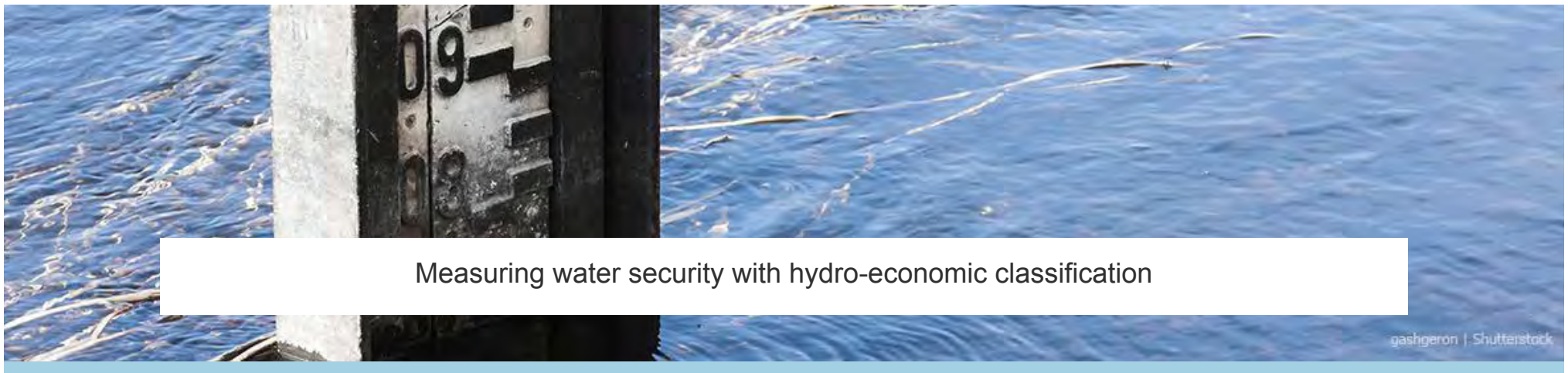
Modeling global water use for the 21st century

Supporting sustainable water policy

Reducing water stress worldwide

Improving efficiency to meet agricultural water demand

Achieving sustainable agriculture



Measuring water security with hydro-economic classification

A novel method to measure water security has been further developed by the IIASA Water Futures and Solutions Initiative. The hydro-economic classification uses two different dimensions to measure water security: the complexity of the hydrology and human water use, and the coping and adaptation capacity.

The IIASA-developed hydro-economic classification evaluates watersheds, countries, or regions using a combination of hydrological complexity and economic-institutional coping capacity [1]. In this way, it can identify vulnerable regions where the prevailing hydro-climatic conditions for human water use are complex and economic-institutional coping capacity is low.

Hydrological complexity is defined on the basis of four indicators:

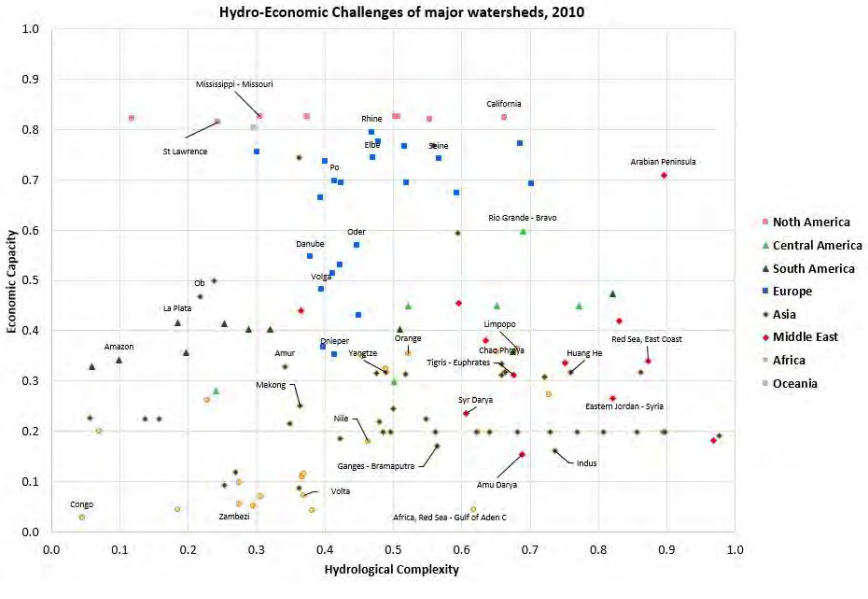
- A measure of water availability, defined as total renewable water resources per capita
- A measure of the relative intensity of water use, defined as the ratio of annual water withdrawal for agriculture, industry, and the domestic sector to the total renewable water resources
- The runoff variability, defined as the variation in monthly runoff for a 30-year period showing both inter- and intra-annual variability
- A measure of the dependency on external water resources, defined as the ratio of external (i.e. from outside national boundaries) water resources to total renewable water resources.

All four indicators were compiled based on data and model calculations consistent with the Representative Concentration Pathways (four greenhouse gas concentration trajectories), and the Shared Socioeconomic Pathways (five possible paths human societies could follow over the next century), which together provide the foundation for global climate modeling.

For economic-institutional coping capacity, researchers selected GDP per capita as a measure of economic strength and financial resources available for investing in risk reduction and adaptation. Although there are some exceptions, GDP per capita can also often provide a proxy for the availability and efficiency of institutions to cope with complex hydrological conditions.

The researchers are also discussing other potential indicators to be included in a measure of economic-institutional coping capacity. For example: education level [2], the Human Development Index, the Worldwide Governance Indicators, the Corruption Perception Index, and the Fragile State Index are all being considered.

The hydro-economic classification can group countries or watersheds into regions facing similar water security challenges and capacities. The Water Futures and Solutions Fast-Track scenario assessment [3] has applied this grouping method to differentiate key drivers of water demand and thereby go beyond globally uniform assumptions.



Watersheds with a population over 10 million people. Less water secure watersheds can be found in the lower right corner of the figure (e.g., Middle East and some Asian ones), while the upper left corner shows basins with higher water security (e.g., North American and European ones)

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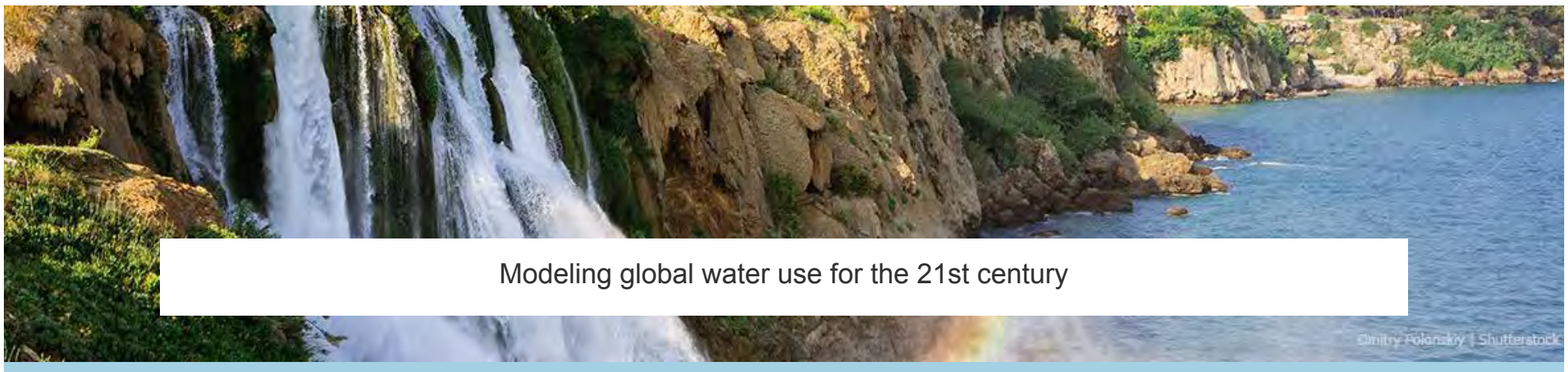
Water Futures and Solutions Initiative



Modeling global water use for the 21st century

The Community Water Model, developed by the IIASA Water Program, assesses water supply and demand at global and regional levels, and includes provision for healthy aquatic ecosystem. The hydrologic model is open source and can be linked to other models, enabling analysis of many different aspects of the water-energy-food-ecosystem nexus.

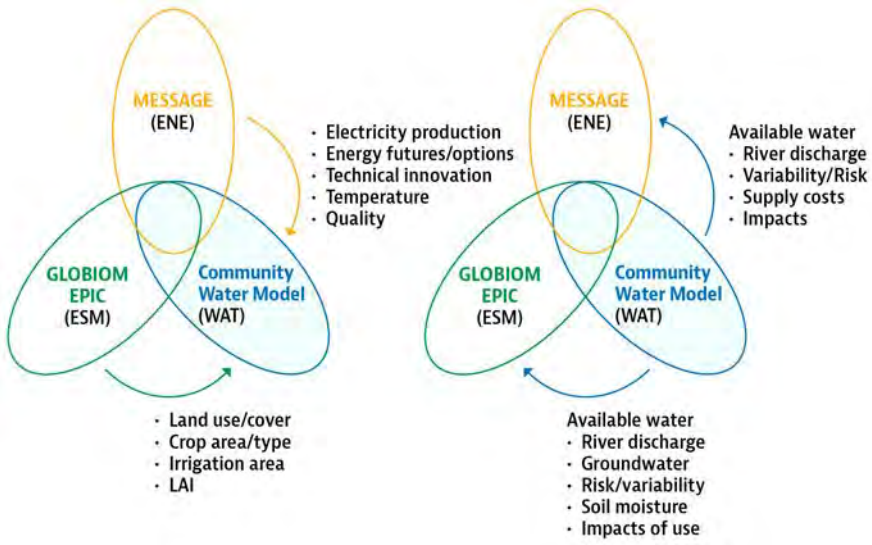
Rising population and growing economic development mean that water demand is expected to increase significantly, especially in developing regions. At the same time, climate change will have global, regional, and local impacts on water availability. Accurate assessment of water supply and demand is therefore vital, and must take into account both human water use and the amount needed to maintain healthy aquatic ecosystems. The Community Water Model will examine how future water demand will evolve in response to socioeconomic change and how water availability will change in response to climate.

The model has been developed to work at both global and regional levels at varying spatial resolutions, and the fact that it is open-source means that it provides a service to the water research and management community worldwide. In addition, it is flexible enough link to further planned developments such as water quality and hydro-economic extensions to the model.

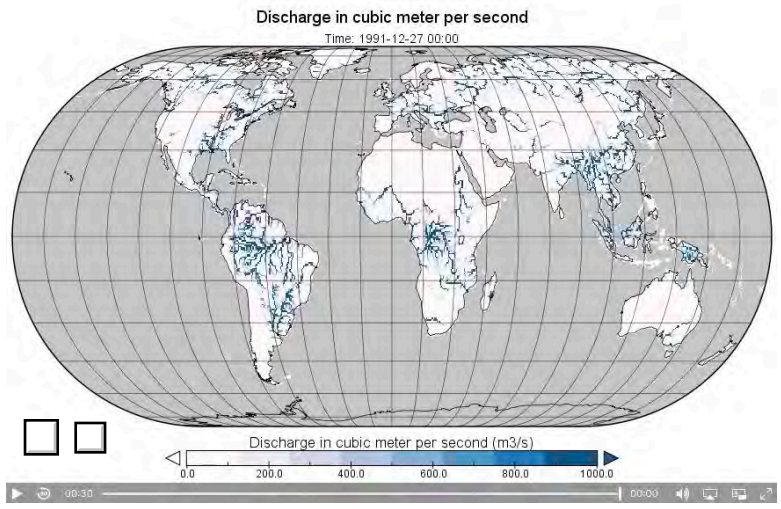
In this way, the model will provide a basis to develop a next-generation global hydro-economic modeling framework that can clarify the economic trade-offs among different water management options, encompassing both water supply infrastructure and demand management. The integrated modeling framework will consider water demand from agriculture, domestic, energy, industry, and the environment. It will also take into account the investment needed to alleviate future water scarcity, and provide a portfolio of economically optimal solutions. In addition, it will be able to track the energy requirements associated with the water supply system; for example, pumping, desalination, and interbasin transfer.

To achieve these goals, the model will be coupled to existing IIASA models, including the Model for Energy Supply Strategy Alternatives and their General Environmental Impact (MESSAGE); the Global Biosphere Management Model (GLOBIOM); and the Environmental Policy Integrated Model (EPIC).

In the short to medium term, the IIASA Water Program is working is to introduce water quality (e.g., salinization in deltas and eutrophication associated with mega cities) into the Community Water Model, and to consider qualitative and quantitative measures of transboundary river and groundwater governance



Linking models for best results. MESSAGE: Model for Energy Supply Strategy Alternatives and their General Environmental Impact from the IIASA Energy Program (ENE). GLOBIOM: Global Biosphere Management Model and EPIC: Environmental Policy Integrated Model from the IIASA Ecosystems Services and Management Program (ESM). Community Water Model from the IIASA Water Program (WAT).



The Community Water Model output, showing global discharge over a one year run example: 1/1/1991- 31/12/1992

IIASA by program

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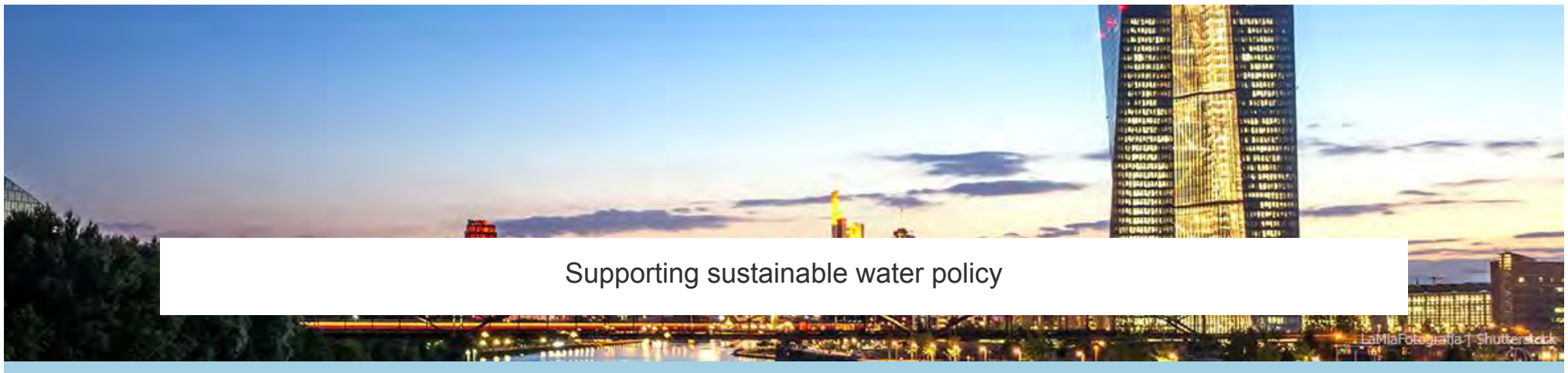
Water Program



Supporting sustainable water policy

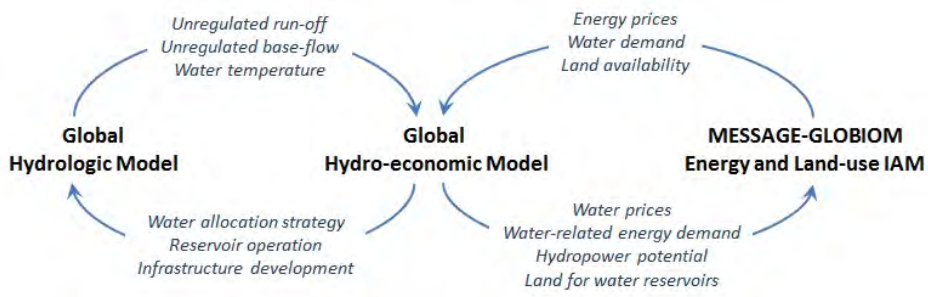
Climate change and growing demand mean that competition for scarce water resources is increasing worldwide. The consequences for the environment and the global economy could be severe. The Global Hydro-economic Model, currently under development by the IIASA Water Program, can be used to simulate a wide range of possible future scenarios, supporting policymakers to create cost-effective, long-term sustainable water management policies.

The pressure on water resources has been mounting worldwide, with water scarcity becoming a widespread problem in most arid and semiarid regions around the world. Global water extractions have increased more than six fold in the last century, which is more than twice the rate of human population growth [1]. However, the impact of growing water scarcity on long-term sustainable development has not been adequately addressed by the integrated assessment research community.

Specifically, the allocation of water resources across regions and sectors at the global level remains largely unaccounted for in long-term modeling. To reconcile potential inconsistencies introduced by constraints on future water availability, IIASA researchers are developing the Global Hydro-economic Model, which will integrate spatially distributed water resource systems, infrastructure, management options, and economic values. In addition, it will be possible to link it with other IIASA integrated assessment models: the Community Water Model; the Model for Energy Supply Strategy Alternatives and their General Environmental Impact; and the Global Biosphere Management Model.

The Global Hydro-economic Model uses optimization to balance global water demand and supply at the level of large-scale river basins. The technique allows the model to minimize the total costs of meeting the water demands from the agricultural, industrial (energy and manufacturing), and domestic sectors, while also taking into account various resource, institutional, and environmental constraints, such as retaining enough water for healthy aquatic ecosystems.

Monthly variation will be included so the model can align with existing IIASA integrated assessment models. The model can be used to simulate a variety of basin management decisions including resource extractions, interbasin transfers, reservoir storage, and water infrastructure investment (i.e., the choice of the size and location of new water projects). The model uses information on water demand and availability provided by existing global integrated assessment models at IIASA and provides information on water resources development and allocation to those models.



The proposed integration of the Global Hydro-economic Model with other IIASA integrated assessment tools.

The development of the Global Hydro-economic Model, which involves several different programs at IIASA (the Water, Energy, and Ecosystem Services and Management programs) is carried out as part of the larger *Integrated Solutions for Water, Energy, and Land* project.

IIASA by program

References

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Water Program

Reducing water stress worldwide

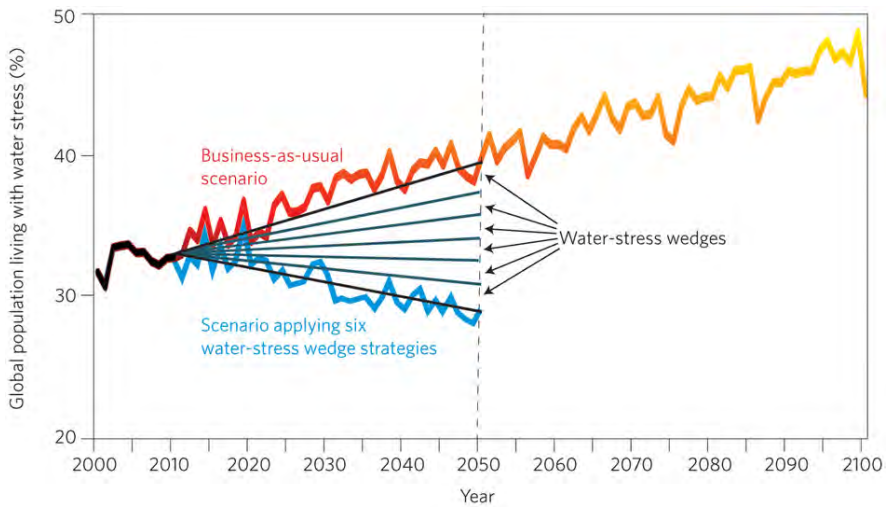
IIASA researchers have identified six water management strategies that can help reduce water stress. Implementing all six strategies, which include increased water recycling and improved irrigation techniques, would reduce the population living with water stress by 12% by 2050.

Water scarcity is not just a problem for the developing world [1]. In California, USA, legislators are currently proposing a US$7.5 billion emergency water plan to their voters; and the US federal officials warned residents of Arizona and Nevada in 2016 that they could face cuts in Colorado River water deliveries. Climate change, wasteful irrigation techniques and industrial and domestic demand lie at the root of the problem, and if current trends continue, water demand would more than double by the year 2050 [2][3][4]. But despite what appears to be an insurmountable problem, it is possible to turn the situation around and significantly reduce water scarcity in just over 35 years, IIASA research has found.

"Water stress" is a term used to describe a situation where more than 40% of the water from the rivers in an area is unavailable because it is already being used [5][6]. Currently, about a third of the global population is affected, and as many as half the people in the world may be coping with water stress by the end of the century, if the current pattern of water use continues [7][8]. Researchers from the IIASA Water Program and their collaborators have outlined six key strategies that they believe can be combined in different ways in different parts of the world to effectively reduce water stress.

The six strategies can be divided into either "hard-path" measures, involving building more reservoirs and increasing sea water desalination, or "soft -path" measures that focus on reducing water demand rather than increasing water supply. These latter often work via community-scale efforts and decision-making, and include improving irrigation efficiency and industrial water use. While there are some economic, cultural, and social factors that may make certain soft-path measures difficult, such as population control, in general the soft path offers a more realistic way forward in terms of reducing water stress.

There is no single silver bullet to deal with the problem around the world. However, by looking at the problem on a global scale, the researchers calculated that if four of these strategies were applied at the same time the number of people in the world who are facing water stress would stabilize rather than continue to grow, which is what will happen if we continue with business as usual. Significant reductions in the number of people suffering water stress are possible by 2050, but a strong commitment and strategic efforts are required to make this happen.



The impact of strategies for reducing global water stress. The six strategies, or water-stress wedges, collectively lead to a reduction in the population affected by water stress by 2050, despite an increasing population. For simplicity, the water-stress wedges are shown here as straight lines, although the proposed efforts are unlikely to produce such consistent and linear results. The climatic variability of precipitation is included in the colored lines, whereas the water-stress wedges are simplified straight-line projections.

Water Program

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Further information

Changing rainfall patterns linked to water security in India

Improving efficiency to meet agricultural water demand

Increased water-use efficiency in irrigation systems can cancel out the impact of the expected expansion of irrigation, new IIASA research has shown. The area of crops under irrigation is expected to rise in the coming decades; however, if irrigation efficiency is improved sufficiently net water demand need not increase.

Water security is under threat worldwide and effective, long-term water management strategies are urgently needed. The IIASA Water Future and Solutions Initiative aims to establish a comprehensive water assessment framework which covers agricultural, industrial, and domestic sectors [1]. In a recent study for the initiative, researchers projected the future trajectories of the key drivers of agricultural water demand: crop and irrigation area, and irrigation efficiency.

As a basis for the modeling the authors used three Shared Socioeconomic Pathways, which describe possible paths human societies could follow over the next century, along with the Representative Concentration Pathways, which are greenhouse gas concentration trajectories. Together, these pathways are used as the foundation for much of the world's global change modeling.

As food demand rises, crop area and irrigation area are both expected to expand, causing an increase in agricultural water demand. The IIASA Global Agro-ecological Zones system (GAEZ) provides projections of the spatial patterns that crop and irrigation areas will follow [2]. These projections take into account different climate scenarios; demographic and socioeconomic factors; production; consumption; and world food trade.

Although water demand is rising, economic and technological progress has the potential to improve water use efficiency. For this work researchers examined irrigation efficiency at a country level, considering all possible combinations of five crop types and three irrigation systems (gravity, sprinkler, and drip irrigation).

Efficiency increases when an existing irrigation system is replaced with an improved irrigation system of the same type, or another higher efficiency system, or when new areas are fitted with a high efficiency system. For this study, therefore, irrigation efficiency was defined as a function of replacement speed and irrigation area, and the researchers assumed that irrigation efficiency would increase with socioeconomic growth.

The GAEZ results indicate that the global area of irrigated land will be 10-15% larger by 2050. Under the sustainability scenario the area of land under irrigation would peak and decline after 2050, but the irrigated area is expected to keep expanding in the other two socioeconomic scenarios (Figure 1).

Irrigation efficiency is expected to steadily improve in all countries because of their economic growth. The biggest improvements were in China (0.6-1.5% efficiency gains per year), India (1.8-2.8% per year), Pakistan (2-3.4% per year), and the USA (0.6-1.7% per year). The results demonstrate that increased irrigation efficiency can cancel out the impact of irrigation area expansion on water demand (Figure 2).

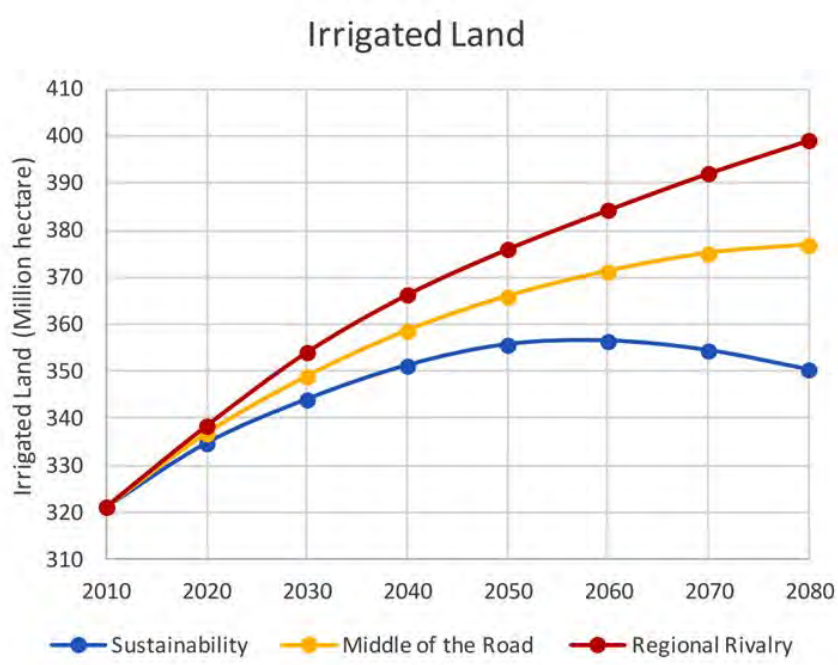

Figure 1. Projections of irrigation area expansion. (a) Projections for each scenarios. Sustainability scenario follows SSP1 (blue), Middle of the Road scenario follows SSP2 (yellow) and Regional Rivalry scenario follows SSP3 (Red).

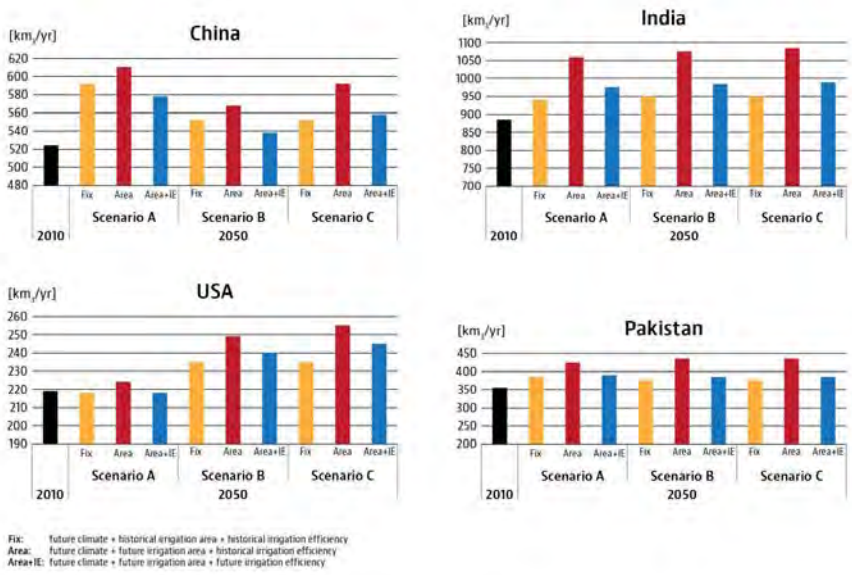

Figure 2. Change in irrigation water demand (in cubic kilometres) comparing 2010 and 2050 under three scenarios (Scenario A: socioeconomic pathway 1 with representative concentration pathway 4.5. Scenario B: socioeconomic pathway 2 with representative concentration pathway 6.0. Scenario C: socioeconomic pathway 3 with representative concentration pathway 6.0). Yellow bars consider only impact of climate change without irrigation area expansion or irrigation efficiency improvement. Red bars include impact of irrigation area expansion as well as climate change but without irrigation efficiency improvement. Blue bars take irrigation efficiency improvement into consideration as well as the other two impacts.

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Water Futures and Solutions Initiative

Collaborators

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Achieving sustainable agriculture

The Global Agro-ecological Zones (GAEZ) system, developed by IIASA and the UN Food and Agriculture organization (FAO), provides policymakers with comprehensive information for rational land use planning. In 2016 the system was updated and used in many countries in Asia and Africa to aid governments in improving their food security and agricultural development.

GAEZ estimates show that 70% of global water withdrawals go to agriculture and as much as 90% of fresh water use is for irrigation. Global net crop irrigation requirements will likely increase by 15-23%above 2010 levels because of climate change and expansion of irrigated areas. However, in many regions an increase of irrigation water withdrawal can be avoided or mitigated by improving the efficiency of irrigation systems and better water and land use management.

GAEZ work has resulted in collaborations around the world, including 2016 projects in Bangladesh, India, Ghana, and Thailand. In Thailand, IIASA collaborated on the project "National Agro-economic Zoning for Major Crops in Thailand," helping to strengthen national capacity for addressing issues of land use and land planning and the sustainable management of natural resources through the establishment of agro-economic zones.

In South Africa, in collaboration with the World Wide Fund for Nature, IIASA used GAEZ to examine the potential availability of sustainable feedstock resources for producing renewable airline fuels in sub-Saharan Africa. The extended GAEZ included additional feedstock crops (including Solaris tobacco and the oil seed plants Camelina and Triticale) and assessed the potential for using them to produce airline fuels while taking into account food security requirements and environmental protection.

The latest GAEZ (version 4) includes updated information on land cover, crop areas, protected areas, renewable water resources, and climatic conditions for the historical period 1961-2010 and for a selection of future climate simulations. The FAO's water balance and accounting model GlobeWat has also been expanded and integrated into GAEZ v4.

In 2016, work also focused on completing the preparation of the GAEZ data portal for release. The data portal will help ensure that UN member countries have sufficient, reliable information on sustainable management of natural resources for food and agriculture to support policy decisions at all scales. The portal provides free and easy internet access to data and information.

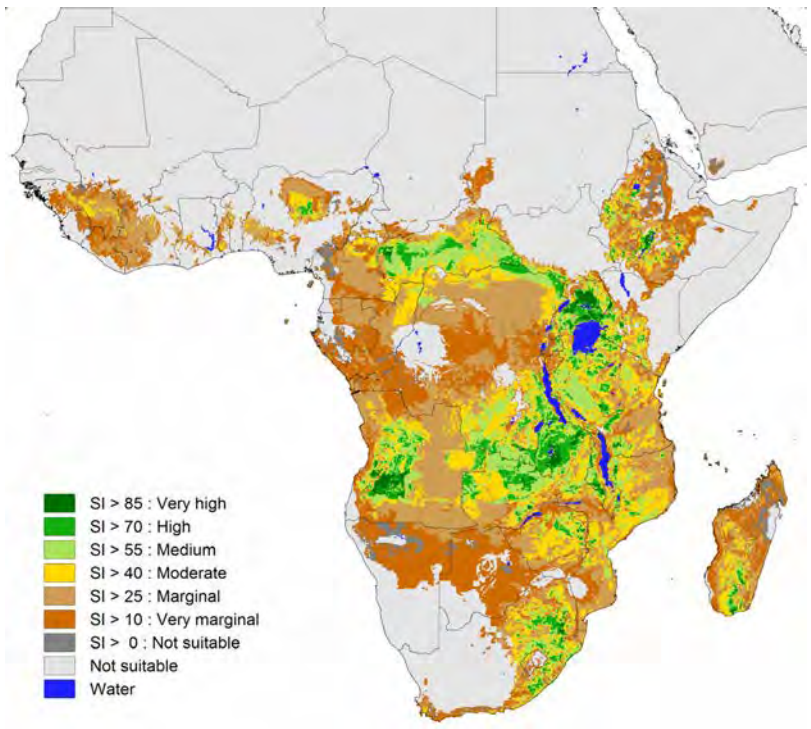

Figure 1: Agro-ecological suitability of rain-fed Solaris tobacco (biofuel feedstock) simulated using GAEZ

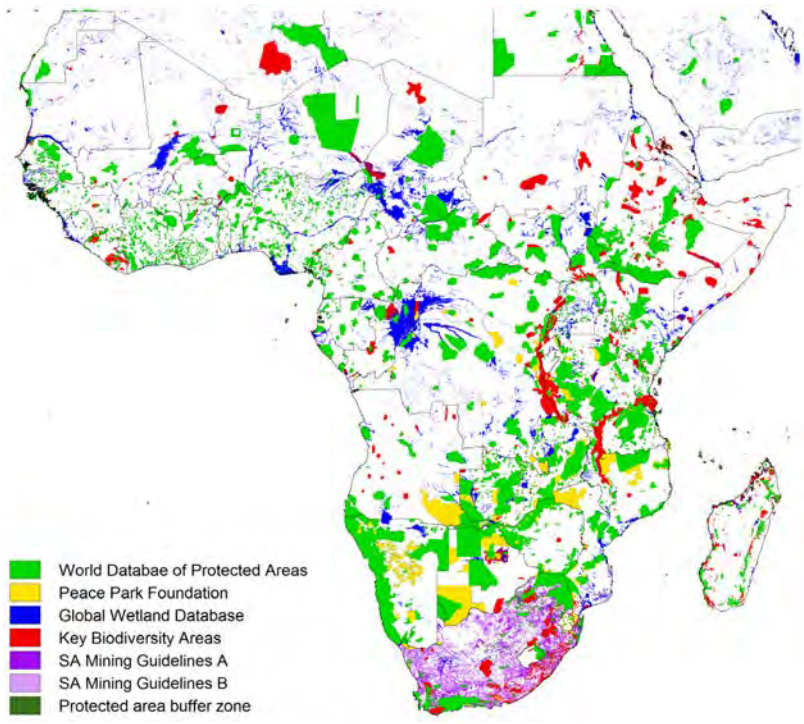

Figure 2: Distribution of 'no go' areas applied in the assessment sustainable biofuel feedstock production in sub-Saharan Africa.

Water Program

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Collaborators

- Food and Agriculture Organization of the UN
- World Wide Fund for Nature South Africa
- Institute of Rural Management Anand, India
- National institute of Hydrology, India
- Centre for Water Resources Development and Management, India
- Shanghai Climate Center, China
- University of Maryland, Department of Geography, USA

Further information

GAEZ v.4 and FAO-GAEZ Data Portal

World Population Program

The World Population Program is a global leader in the comprehensive study of the changing number, distribution, and composition of humans on the planet and the effect of these changes on sustainable development. This is essential to complement IIASA work on environmental topics, and makes IIASA the only global change research institute with significant in-house competence on the human population and its wellbeing.

Program website
Scientific recognition
Publications
Staff
Events

Objectives

- Expand the multi-dimensional model of population dynamics developed at IIASA to include an urban/rural dimension for all countries.
- Define and test alternative specifications of Empowered Life Years, which are the years a person can be expected to be alive and "empowered"— as measured by health, ability to read, freedom from poverty, or subjective life satisfaction.
- Produce the first systematic projections of new indicators of aging, which will explicitly reflect additional dimensions for most European countries and selected other Organisation for Economic Co-operation and Development (OECD) counties. This will go beyond the conventional simplistic indicators which only reflect chronological age.
- Provide policymakers with data pertaining to the likely proportions of urban populations and the changing age and education structure of urban populations.
- Provide governments and civil society guidance as to what pathways are the most promising for reaching sustainable human wellbeing in the longer term.
- Undertake science-policy dialogues on new measures of aging and the relationship to macro-economic impacts of demographic trends.

Selected highlights

Who are the refugees?

New ways to measure age and aging

Sustainable Development Goals lead to lower population growth

Education matters for all Sustainable Development Goals

UN Global Sustainable Development Report

Russian Demographic Data Sheet


Nicolas Economou | Shutterstock

Who are the refugees?

In the first study of its kind, IIASA researchers assessed the skills, attitudes, and values of asylum seekers and refugees, showing that those who entered Austria in the summer and fall of 2015—especially those from Syria and Iraq—are fairly well educated, have rather liberal values, and come from predominantly middle-class backgrounds.

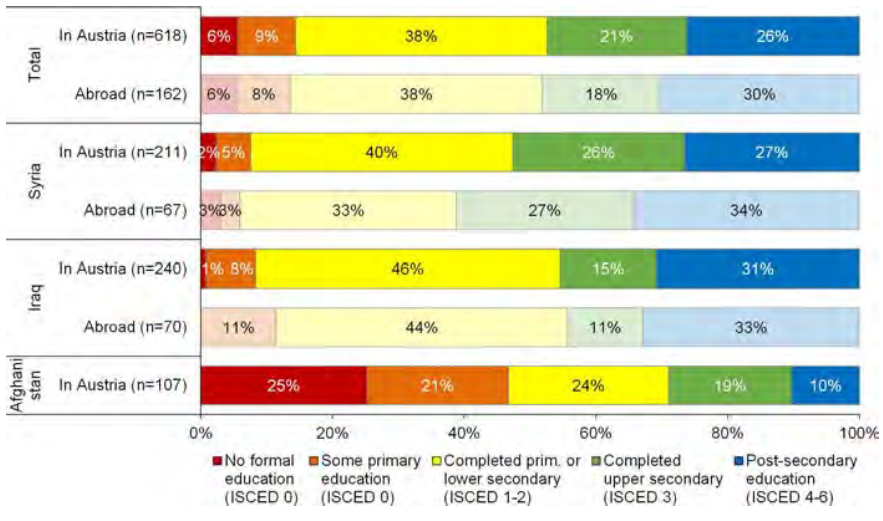
To assess the integration potential of refugees, it is important to learn about their education, professional qualifications, attitudes, and hopes for the future. The new study from the Vienna Institute of Demography and IIASA World Population Program investigated these features for the first time in a German-speaking country.

Contrary to the widely held views that asylum seekers and refugees are uneducated, the study showed that almost half of the respondents from Syria and Iraq had completed secondary education, and more than a quarter had at least obtained a post-secondary degree, such as a high-school diploma or a higher education degree. This is roughly the same as the percentage of people with post-secondary education currently resident in Austria, according to the research team.

For the study, which was published in the internationally renowned journal *PLOS ONE,* a team of researchers surveyed 514 asylum seekers and refugees from both sexes and different ages, mainly from Syria, Iraq, and Afghanistan, in November and December 2015, leading to a sample of around 1,400 people. Face-to-face interviews were conducted to question respondents about their origins, education, professional experience, marital status, attitudes, values, and future plans.

The high level of education is reflected in the values and attitudes of the respondents, who overall view themselves as not particularly traditionally oriented. Asylum seekers and refugees in Austria consistently identified themselves as more liberal than the population in their home countries, assessed using the "World Values Survey," which investigates attitudes on issues such as religion and gender relations in Arab countries. Nearly a quarter of the respondents declared themselves not to be religious at all, and a significant majority of the surveyed men and women agreed with the statement that "having a job is the best way for a woman to be an independent person."

The researchers hope that these results will contribute scientific facts to the public debate about the integration of asylum seekers and refugees. According to World Population Program Director Wolfgang Lutz, the study implies that "the potential for integration of refugees who came to Austria last year is encouraging: high education levels, rather liberal attitudes, and a firm affiliation with the middle classes of their respective countries of origin are good conditions for fostering successful integration into European societies."



Educational attainment of asylum seekers surveyed and their spouses and adult children in Austria (saturated colors) and abroad (pale colors), 20–59 age group. Source: DiPAS

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[1] Buber-Ennser I, Kohlenberger J, Rengs B, Al Zalak Z, Goujon A, Striessnig E, Potančoková M, Gisser R, et al. (2016). Human Capital, Values, and Attitudes of Persons Seeking Refuge in Austria in 2015. *PLoS ONE* 11 (9): e0163481.

World Population Program

Collaborators

- Vienna Institute of Demography (VID), Austrian Academy of Sciences, Austria
- Vienna University of Economics and Business (WU), Austria

Further information

On the blog: Why are the refugees who came to Austria in 2015 more educated than expected?


Halfpoint | Shutterstock

New ways to measure age and aging

Defining aging by physical and mental health rather than chronological age makes global population aging look less rapid, research from the IIASA World Population Program shows. It is important to have these characteristic-based measures of age in addition to conventional chronological age, not only because behavior is influenced by expected remaining life expectancy, but because important economic and social aspects depend on it as well.

Most studies of population aging focus on only one characteristic of people: their chronological age. Many other important characteristics, such as physical and mental health, do vary with age, but they also vary over time and from place to place. IIASA research has supplemented traditional measures of aging with new ones that consider characteristics including remaining life expectancy, health, or hand-grip strength.

Many social and economic factors are influenced by these kinds of characteristics. For instance, retired people are already more likely to take courses to help them enjoy new leisure-time activities because they expect to live longer. The number of requests for the provision of certain medical procedures also depends on the number of remaining years of life.

These findings also have consequences for policy. For example, medical expenditures are especially high in the last years of life. In forecasting these expenditures, it is important to take into consideration that, with increasing life expectancies those last years of life happen at an ever older age. Forecasting medical expenditures only on the basis of chronological age produces figures that are too high and could lead to erroneous policy decisions.

Pension policy can also be informed by this research. A simple alternative public pension system can also be developed using the concept of α-ages. These correspond to different characteristics of the population and allow us to specify a pension system where the fraction of adult years spent eligible for a pension remains constant. Such a system is equitable in the sense that the ratio of the number of years of pension to the number of years of working remains fixed, even as life expectancy changes. This may help in assessing policies concerning the age at the entitlement to a full public pension.

One of the most commonly used measures of population aging is the change in the "old-age dependency ratio." This ratio relates the number of "old-age dependents," who are traditionally assumed to be everyone 65+ years old, to those assumed to support them, people from 20–64. However, rather than assuming everyone over 65 is dependent IIASA researchers use people's characteristics to define old age, such as a remaining life expectancy of 15 years or less. Figures 1 and 2 show the difference in population aging statistics when using a traditional approach and a prospective, characteristics-based approach. These figures illustrate that predictions for population aging are not nearly as extreme if a characteristics approach is used.

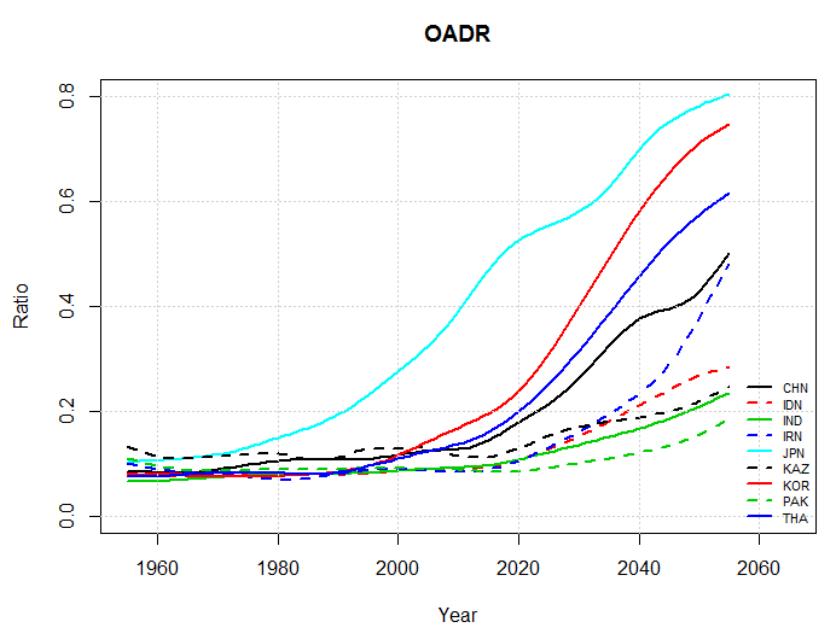

Figure 1. Traditional old-age dependency ratio (OADR) (selected Asian countries), 1955-2055.

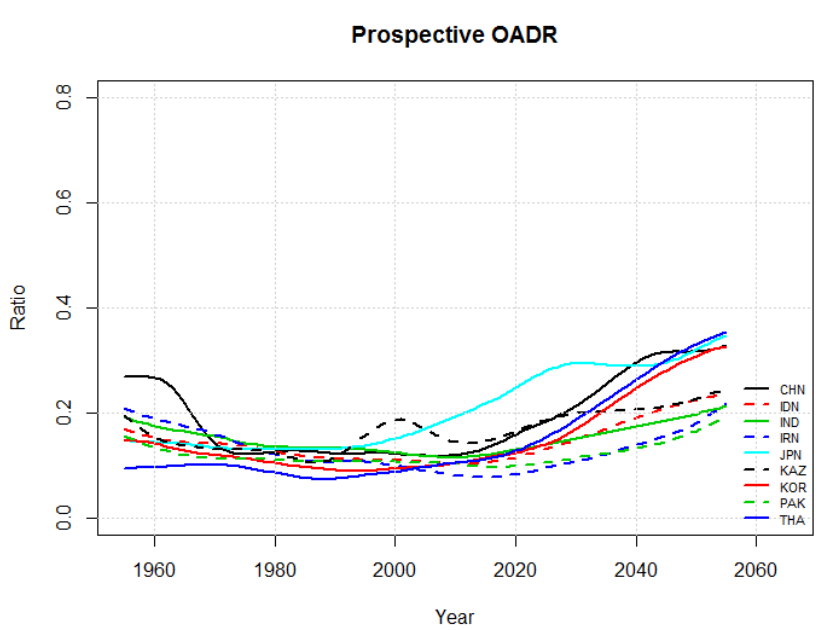

Figure 2: Prospective old-age dependency ratio, based on a remaining life expectancy of 15 years or less (selected Asian countries), 1955-2055.

References

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World Population Program

Further information

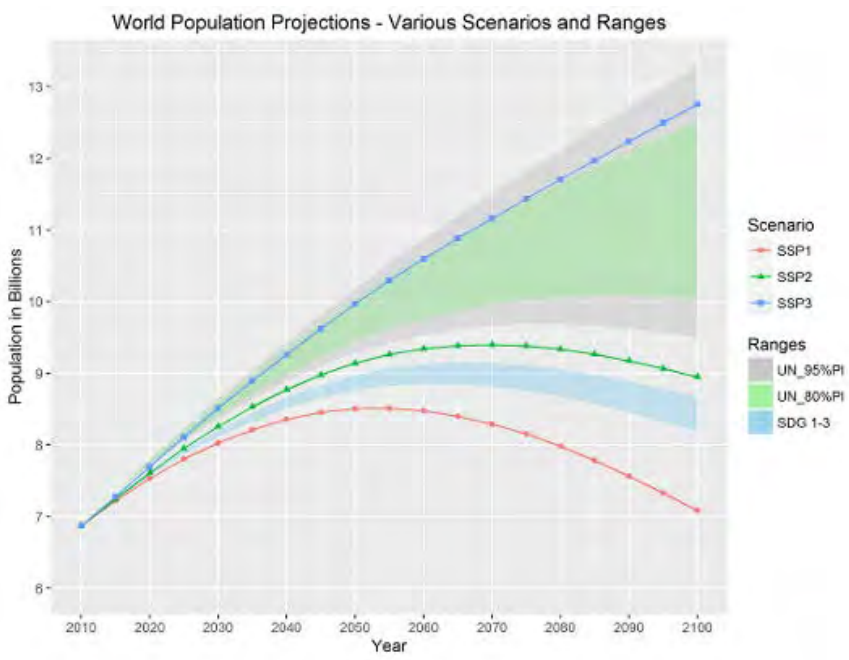
Funding: ERC-funded Reassessing Aging from a Population Perspective (Re-Aging) project (under Grant ERC2012-AdG 323947-Re-Ageing).

Sustainable Development Goals lead to lower population growth

Achieving the Sustainable Development Goals would significantly slow population growth, a landmark study from the IIASA World Population Program shows.

Achieving the Sustainable Development Goals (SDGs) set by the UN in 2015 for the period up to 2030 would lead to a global population of between 8.2 to 8.7 billion by 2100, according to a new study conducted by IIASA and the Asian Demographic Research Institute at Shanghai University. According to the study, published in the journal *Proceedings of the National Academy of Sciences*, achieving the SDGs would lead to population growth below even the lower bound of recent UN probabilistic population projections.

The SDGs include 17 goals with 169 different targets, aimed at fighting poverty, reducing inequality, and addressing climate change, while leaving nobody behind. They include goals such as quality primary and secondary education for all children, gender equality, and reduced child mortality, which all have direct and indirect impacts on population growth.



The IIASA projections assess three different scenarios for the implementation of the SDGs, focusing on the goals that could impact fertility and mortality rates and thus population growth. Data are freely available on the IIASA website www.iiasa.ac.at/SDGscenarios2016

Although population is not mentioned in any of the 169 SDG targets, many people think it is a decisive factor for global environmental change and future human wellbeing. The study is the first to assess how successful implementation of the SDGs would affect population growth. Assuming that for the period 2015-2030 the goals will serve as a turbo boost for development, it finds that achieving the SDGs would lead to global population peaking by 2060, and declining to between 8.2 and 8.7 billion by 2100.

The effects of increasing female education on lowering birth rates in developing countries, and the health target that includes universal access to reproductive health services are the key factors. Achieving these two goals, the study showed, would lead to reduced fertility rates in much of the developing world. The researchers note that achieving the SDGs would also lead to reduced mortality, which would tend to increase population, but that in the longer term, decreased mortality rates also contributes to lower birth rates.

Even if the goals were only partly achieved, the study finds potentially significant decrease in population growth. However, if the international community fails to reach the SDGs then world population growth will be higher, people will be poorer and in worse health, and more vulnerable to environmental change.

The new projections fall outside of the 95% confidence range of 2015 UN probabilistic projections, which range from 9.5 to 13 billion in 2100. The study provides sensitivity analyses of key model assumptions and starting data uncertainty, indicating that the UN projections may have too small a range of uncertainty.

References

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World Population Program

Collaborators

- Asian Demographic Research Institute, Shanghai University, China


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Education matters for all Sustainable Development Goals

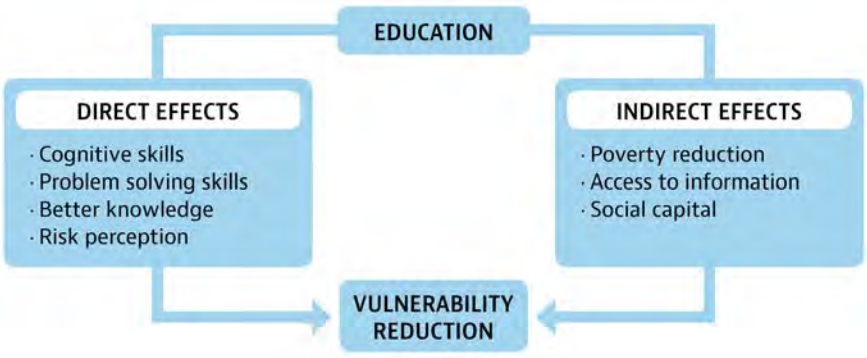
The Global Education Monitoring Report 2016 established that education is at the heart of sustainable development. IIASA made a considerable contribution to the report, which, according to IIASA Distinguished Visiting Fellow Jeffrey Sachs: "should set off the alarm bells around the world and lead to a historic scale-up of actions to achieve Sustainable Development Goal four: education for all."

The Global Education Monitoring (GEM) report is an editorially independent, evidence-based annual report published by UN Educational, Scientific and Cultural Organization, which provides an authoritative global review of education. Its mandate is to monitor progress towards the education targets in the new Sustainable Development Goals (SDGs) framework. The GEM report draws on the latest available data and evidence, and includes extensive research from leading experts around the world.

In 2016, scientists from the IIASA World Population Program were invited to make a contribution on the topic "Education and the SDGs: Long-Term Interactions." This involved producing a comprehensive literature review of the current evidence on education's impact on other key sectors of development, such as inclusive economic growth; inclusive social development; environmental sustainability; governance; and peaceful, just, inclusive societies. This review examined interlinkages between the different SDGs, in particular looking at how progress towards achieving the education goal four will help to achieve the other 16 goals. The researchers also modeled different future scenarios for projecting patterns of education expansion if the SDG targets are met [1].

Examining the issue from four angles—people, planet, prosperity, peace— the analysis shows there are numerous synergies between education and the other SDGs. In terms of "people" the effect of education on social development, including health, is well known. The chapter on "planet" focuses on the role of education (both in terms of formal schooling and interventional education) in reducing vulnerability to climate change and promoting sustainable lifestyles through both direct and indirect mechanisms.

A large number of studies demonstrate how formal education reduces vulnerability in the face of natural disasters, building resilience and adaptive capacity. When it comes to sustainable lifestyles, the relationship is quite complex: while the highly educated are more likely to be concerned about the impacts of their behaviors on CO_2 emissions and the environment in general, their associated higher income levels tend to mean higher consumption levels and higher emissions.



The processes through which education contributes to vulnerability reduction

A review of over 50 studies reveals mixed evidence, though the finding that the more highly educated are more willing and more able to adopt new technologies suggests that formal education may be key to ensuring environmental sustainability in the long term.

The chapter on "prosperity" explores the concept of inclusive economic growth in relation to education. Inclusive growth is spread across all sectors, creating productive employment opportunities for the majority of the labor force, including traditionally marginalized groups. The review of the literature reveals that education can promote broad-based, fast, sustainable economic growth by contributing to the movement of labor from less productive agriculture to more productive manufacturing and services, and by making workers more productive.

The quantitative scenarios of educational expansion underlying the population projections presented in the report are the result of refinement of the education model presented in [2]. The projections showed the share of the population reaching or exceeding a given attainment level in different countries and between genders.

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World Population Program

Collaborators

- Vienna Institute of Demography (VID), Austrian Academy of Sciences, Austria
- Vienna University of Economics and Business (WU), Austria

UN Global Sustainable Development Report

Before leaving office, former UN Secretary-General Ban Ki-moon appointed IIASA World Population Program Director Wolfgang Lutz to be one of 15 independent scientists to draft the official report on progress towards the Sustainable Development Goals. This will be presented directly to the heads of state and government at the UN General Assembly 2019.

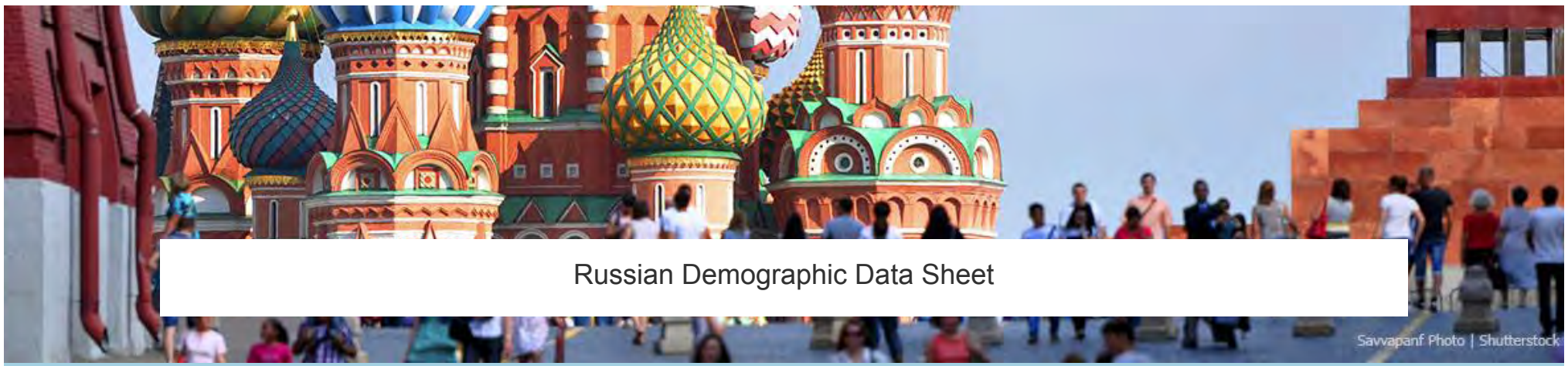
The Global Sustainable Development Report will review the progress made on the 2030 Agenda for Sustainable Development and the Sustainable Development Goals, strengthening the science-policy interface at the High Level Political Forum on Sustainable Development—the main UN platform providing political leadership and guidance on sustainable development issues at the international level. The report, to be published every four years, will provide a strong evidence-based instrument to support policymakers in promoting sustainable development with a special view on the synergies and trade-offs that exist among the different goals.

Unlike other reports commissioned by the UN, this report will not be a negotiated document but rather a completely independent science-based assessment, strengthening the science-policy interface. It will also involve the international scientific community as much as possible to help implement the 2030 Agenda by examining lessons learned, addressing emerging issues, and highlighting emerging trends. It will adopt an integrated approach and examine and evaluate different policy options.

Following an extensive open selection process in consultation with UN member states and relevant organizations, then UN Secretary-General Ban Ki-moon, invited 15 eminent scientists from a wide range of scientific disciplines draft the GSDR, among them IIASA World Population Program Director Wolfgang Lutz.

"Unlike the Intergovernmental Panel on Climate Change and other intergovernmental processes, the report independently produced by this group will not require approval by governments but will be published directly and serve as basis for discussions in the General Assembly as well as other high-level UN bodies. It will be a particular challenge to find ways to facilitate input from scientific academies and other scientific bodies who have relevant information and analyses to contribute to this report," said Lutz.

World Population Program



Russian Demographic Data Sheet

The IIASA Russian Demographic Data Sheet 2016 reviews key population trends in Russia, and gives a population projection for the country for 2035. The sheet allows experts to analyze the country's regional demography and demographic processes.

The Russian Demographic Data Sheet 2016, available in Russian and English, uses a number of the latest demographic indicators regarding population growth and aging, many of which were calculated for Russia for the first time. Led by World Population Program Deputy Director Sergei Scherbov, the sheet uses cutting-edge mortality, fertility, and migration models—more sophisticated than previously available. These were used by the researchers to evaluate age-specific transitions and transition rates based on the aggregate scenario definitions prepared by the Russian Federal State Statistics organization.

A unique feature of the data sheet is the introduction of new measures of aging, developed at IIASA. These include the "prospective old-age dependency ratio." The traditional old age dependency ratio relates the number of "old-age dependents," who are assumed to be everyone 65+ years old, to those assumed to support them, people from 20–64. However, rather than assuming everyone over 65 is dependent, the prospective old-age dependency ratio defines an old-age dependent as someone with a remaining life expectancy of 15 years or less. Variation in the number of individuals with a remaining life expectancy of 15 years or less was calculated for each region of Russia, and presented for the first time.

Additionally, a zero-migration scenario was also introduced. It allowed evaluation of the consequences of internal and external migration on population size and composition in regions within Russia. The zero-migration scenario led to a population reduction of about 4% by 2035 compared to contemporary population size, while the scenario including migration led to a basically unchanged population size.

The data sheet was presented at the high-level Gaidar Forum in January 2017 in Moscow. In a dedicated session at the conference, Scherbov presented the methodological background of the applied new methods and the major results to journalists, scientists, and policymakers from across Russia.

The Russian Demographic Data Sheet presentation and panel discussion at the Gaidar Forum. From left to right: Tatyana Maleva (director at the Institute of Social Analysis and Forecasts), Sergei Scherbov (IIASA World Population Program Program deputy director), Professor Dr. Pavel Kabat (IIASA director general and CEO), Wolfgang Lutz (IIASA World Population Program director), Konstantin Laykam (deputy head of the Federal Service of State Statistics), and Valery Yelizarov (head of the Center for Population Studies, Lomonosov Moscow State University).

References

[1] Presidential Academy of National Economy and Public Administration, Russian Federal State Statistics Service, & the International Institute for Applied Systems Analysis (2016). *Russian Demographic Data Sheet 2016*. RANEPA, Rosstat, and IIASA: Moscow, Russia and Laxenburg, Austria.

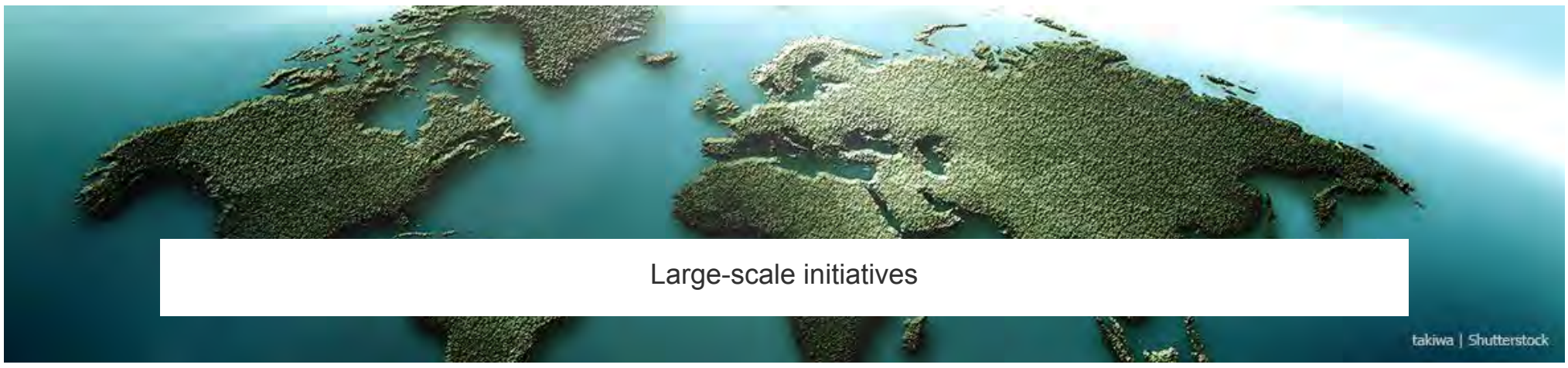
World Population Program

Collaborators

- Russian Presidential Academy of National Economy and Public Administration
- Russian Federal State Statistics Service

Further information

- The research was conducted in the framework of the ERC funded Reassessing Aging from a Population Perspective (Re-Aging) project (under Grant ERC2012-AdG 323947-Re-Ageing).
- IIASA at the Gaidar Forum 2017

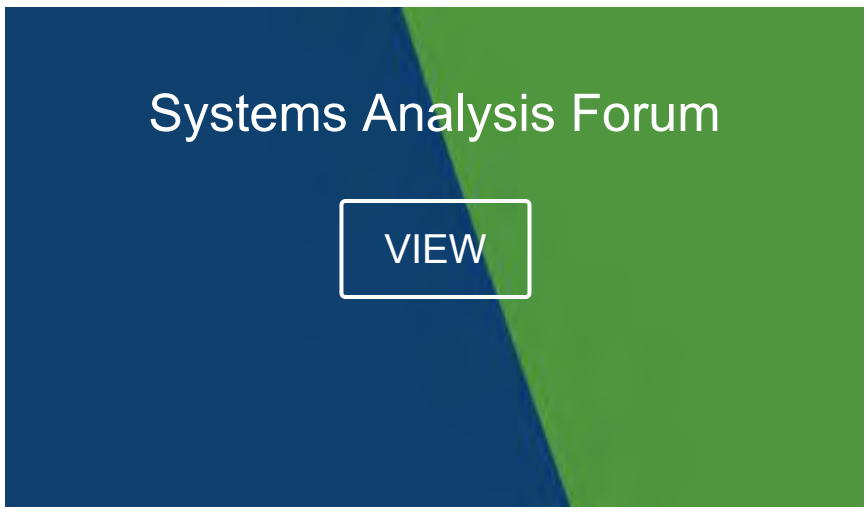


Large-scale initiatives

The IIASA futures initiatives are designed to explore plausible futures for a number of the world's rapidly transitioning regions or resources. The initiatives range from helping both the Arctic and the Tropics to develop sustainably under rapid global change, to exploring economic cooperation across Eurasia, to improving water security worldwide.

Integrated, interdisciplinary approaches that identify feedbacks, trade-offs, and co-benefits of policy decisions are needed to resolve global sustainability challenges. These projects bring together expertise from across all the institute's programs and external networks, to address the research objectives at both global and regional scales.

These methodology-focused projects represent unique and unaddressed research challenges that require integrated and interdisciplinary expertise and focus. They address not only cutting-edge research questions, but, by drawing upon expertise from across all IIASA research programs, also promote greater collaboration across the institute.



Accelerating global change and rising levels of interconnectedness necessitate new methods for identifying scientifically sound policy advice. The Systems Analysis Forum helps foster methodological innovations inspired by applied research at IIASA; promoting exchanges among the institute's researchers and methodological experts around the world.

Futures initiatives

Arctic Futures Initiative

The Arctic is undergoing a vast and rapid transformation and this futures initiative works collaboratively with key organizations in the region to support decision makers in this time of complex global change.

Initiative website

Arctic resilience in a changing world

Health, wellbeing, and aging in the Arctic

Loss and damage in the Arctic under climate change

Eurasian Economic Integration

This international and interdisciplinary futures initiative analyzes the possibility of economic cooperation between the EU, the Eurasian Economic Union, and their neighbors, potentially extending to the USA and key Asian players, such as China, India, and others.

Initiative website

Labor market and migration across Eurasia

Economic cooperation between the EU and Eurasian Economic Union

Tropical Futures Initiative

Tropical rainforests are home to the greatest biodiversity on the planet and provide vital climate regulation. The Tropical Futures Initiative aims to help policymakers pick out a sustainable path for this important part of the globe.

Initiative website

Wildfires of the future

Energy and landscape sustainability in Indonesia

Negative emissions in the tropics

Water Futures and Solutions Initiative

The Water Futures and Solutions Initiative is a cross-sector initiative which helps identify water management policies that work together to improve water security. It has developed a stakeholder informed, scenario-based assessment of water resources and demand.

Initiative website

Measuring water security with hydro-economic classification

Modeling global water use for the 21st century

Improving efficiency to meet agricultural water demand

Water security in Asia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Arctic resilience in a changing world

The Arctic Resilience Report is the first comprehensive assessment of ecosystems and societies in the region. It identifies 19 "tipping points" in natural systems that could radically reshape the Arctic in the coming century, and calls for urgent cooperation to build local communities' resilience and capacity to adapt to rapid and widespread change.

A tipping point is a rapid change that can have severe and often irreversible effects on ecosystems. The report identified several that might effect the Arctic, including the growth in vegetation on tundra, which replaces reflective snow and ice with darker vegetation, thus absorbing more heat; higher releases of methane, a potent greenhouse gas, from the tundra as it warms; and the collapse of some key Arctic fisheries, with could affect other ecosystems even in distant oceans.

The report, produced under the auspices of the Arctic Council and with input from an IIASA Arctic Futures Initiative researcher, also examines how different Arctic peoples adapt to change, providing multiple examples of communities which have maintained traditional whaling, reindeer herding, and other practices. Many have transformed the way they live and interact with nature and natural resources. For example, the fishing community of Húsavík, Iceland, has turned itself into a tourist destination for whale-watching after cod-fishing quotas and a moratorium on whaling ended their traditional livelihoods. It also profiles cases where local communities have lost their livelihoods and are struggling to survive, maintain their cultural identity, or both.

The report found four key factors that helped communities build resilience:

- Capacity for self-organization – that is, to make decisions and implement responses to change
- Diversity of responses to change
- Capacity to learn from and integrate diverse types of knowledge
- Capacity to navigate uncertainty and surprises

Unfortunately some policies and actions taken by Arctic country governments prevent resilience. As well as avoiding these damaging practices, governments should increase their efforts to support and empower local communities to prepare for shocks and stress, the report concluded.

The Arctic Resilience Report, launched in November 2016, is the culmination of a five-year scientific effort and will be presented to the eight Arctic nations' foreign ministers during the Arctic Council Ministerial Meeting in Fairbanks, Alaska on 11 May 2017.

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Arctic Futures Initiative

Collaborators

- Arctic Council
- Stockholm Resilience Centre
- Stockholm Environment Institute

Health, wellbeing, and aging in the Arctic

Arctic communities may have significantly different aging patterns to those in the southern areas of the same country, IIASA research has shown. Using new measures of aging they showed that national policies should be adjusted to take into account these differences. In a second study, the Arctic Futures Initiative looked into variation in wellbeing across the Barents region, emphasizing the importance of education to facing socioeconomic challenges and adapting to climate change in these northern countries.

Population aging has the power to transform small communities in the Arctic, and policies on important social factors, such as care for the elderly, must be designed with this in mind. In a 2016 study, IIASA researchers applied new measures of aging developed at IIASA. Known as "prospective age," these measures look at the number of years a person has left to live, so a healthy person of 60 years old may have the same prospective age as someone in bad shape at 45. They found that population aging in remote Arctic territories is different, sometimes significantly, from the ''mainland'' (e.g., Greenland versus Denmark or Nunavut versus Canada). Policies related to aging should be adjusted to the specifics of the Arctic, the researchers conclude, rather than following nationwide patterns [1].

In another study, a member of the Arctic Futures team examined wellbeing in the Barents region, incorporating population, health, education, and environmental factors. In parcticular, they analyzed recent demographic trends across gender and ethnicity, including depopulation, aging, mortality, and fertility. They also investigated the impacts of air and water contamination, food insecurity, housing conditions, and new climate-change driven diseases on the health and living conditions of the Barents people.

The results showed that these factors varied significantly across the Barents region and this variation has been increasing in recent decades, despite efforts to harmonize development in the region [2]. The study also highlighted the importance of education in tackling socioeconomic challenges as well as adapting to climate and other sweeping changes occurring in the Barents region.

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Arctic Futures Initiative


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Loss and damage in the Arctic under climate change

IIASA researchers have reviewed the latest studies on the impacts that climate change will have on the Arctic, from its delicate environment to its local communities. The results show that some changes will be so sweeping that they may go beyond the bounds of adaptation, and a case can be made for international support for the victims of this climate-related loss and damage.

Climate change will have severe impacts on the Arctic, both scientific evidence and traditional knowledge show, and those risks and impacts may also have global consequences. To assess exactly what those impacts might be, an IIASA researcher reviewed the latest studies on the consequences of climate change for the Arctic region and their implications for identifying risks beyond adaptation and supporting the victims of climate-related loss and damage.

Climate related risks and impacts are not distributed equally in the Arctic, the review revealed. And although some Arctic countries have high adaptive capacity, under conditions of rapid change current institutions and government mechanisms are not sufficient to deal with the multiple challenges of change, which include climate change, environmental degradation, and the pressure of new businesses coming to the Arctic.

Another key finding was that climate change increases the vulnerability of local and indigenous communities across the region. Land-based livelihoods, such as reindeer husbandry, can be affected by climate change directly because of shrub growth, which absorb heat more than snow or ice, and will exacerbate regional warming. Livelihoods can also be indirectly affected by increased economic interest in exploitation of natural resources, which can lead to land-use conflicts. Sea-level rise and coastal erosion are also forcing people to emigrate or relocate away from coastal communities. This can have negative impacts on society and culture, and raises questions about the limits to adaptation.

One important issue the review highlighted is the lack of local capacity or an international institutional framework to organize relocation. As people have to move away from their communities many feel this can no longer be classed as 'adaptation' and therefore should be considered loss and damage worthy of support by the international community. Relocation can also have multiple negative consequences, especially in indigenous communities who are facing loss of their traditional livelihoods and culture.

There is a need for (re-)identification of roles and responsibilities in international climate policy, especially in terms of liability and compensation mechanisms and international institutional support to define the limits of adaptation, the review concluded.

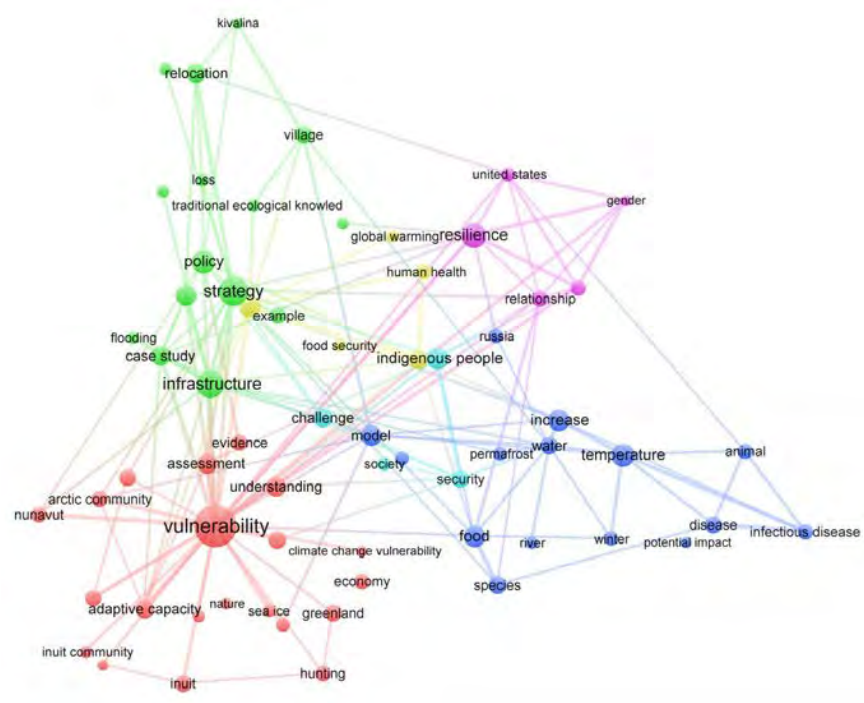

Figure: *Arctic loss and damage-related studies as a "keyword mining" visualization. The 'term map' visualizes main topics found in the articles. The figure shows the essential keywords related to the Arctic loss and damage topic that are most frequently encountered, extracted from the article titles and abstracts. Overall 83 terms that met the threshold of appearance 10 times were selected. The size of the circles indicates frequencies of keywords. Circle colors indicate close relatedness of the terms (substance-wise). The terms marked with the same color form a cluster of related terms that can be seen as a topic. Lines express co-occurrence of the terms between the clusters either in the article title, or abstract, or both (N=164). Created by Maria Söderholm from Aalto University, Finland.*

Collaborators

- Loss & Damage Network: Deltares, Netherlands London School of Economics, UK
- Fondazione Eni Enrico Mattei, Italy
- Basque Centre for Climate Change, Spain
- University of Oxford, UK
- Institute for Environmental Studies, Vrije Universiteit Amsterdam, Netherlands
- University of Salzburg, Austria
- University of Wellington, New Zealand
- International Center for Climate Change and Development, Bangladesh
- Practical Action, UK
- UN University, Institute for Environment and Human Security, Germany
- Climate Analytics, Germany
- University of Graz, Austria
- Vienna University of Economics and Business, Austria University of Vienna, Austria
- Universität Zürich, Switzerland
- University of Helsinki, Finland
- Aalto University, Finland

Arctic Futures Initiative

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Labor market and migration across Eurasia

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The impact of migration flows on the sustainable development of Eurasia, labor market challenges, and the harmonization of education systems in the EU and the Eurasian Economic Union (EAEU) are complex and controversial topics. In 2016, IIASA provided the only platform to date that has brought together experts and policymakers from East and West to discuss these issues.

The workshop, part of the IIASA project *Challenges and Opportunities of Economic Integration within a Wider European and Eurasian Space*, was attended by over 50 well-established academics and policymakers from Europe, the post-Soviet space, Turkey, the Republic of Korea, and the USA. The participants discussed possible scenarios of cross-border migration (both labor migration and refugee flows) and the changing structure of the labor force, as well as their economic and social implications for the labor markets and the economic growth of both the source and host countries in the EU, the EAEU, and the countries in their joint neighborhood. They also considered practical aspects such as the prospects of introducing a visa-free regime between the EU and the EAEU, enhancing the reciprocal recognition of labor migrants' pension rights between countries, fostering educational and academic exchanges, and the mutual recognition of diplomas [1].

At a high-level panel session, participants reflected on the long-term prospects of economic cooperation between the EAEU, the enlarged EU, and their neighbors, including the key Asian players such as China, Japan, the Republic of Korea, as well as the USA, focusing on labor market challenges and the impacts of migration flows on the sustainable development of the Greater Eurasian region.

The session was chaired by Pavel Kabat and included talks by Tatyana Valovaya, Václav Klaus, Jeffrey D. Sachs and Péter Balás, as well as Evgeny Vinokurov, Peter Havlik and Jesus Crespo Cuaresma.

Evgeny Vinokurov (Senior Research Scholar, Advanced Systems Analysis Program, IIASA), H.E. Tatyana D. Valovaya (Member of the Board – Minister in charge of Integration and Macroeconomics of the Eurasian Economic Commission), and Professor Dr. Pavel Kabat (Director General and CEO, IIASA)

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Challenges and Opportunities of Economic Integration within a Wider European and Eurasian Space

Economic cooperation between the EU and Eurasian Economic Union

Deep, comprehensive, long-term economic cooperation between the EU, the Eurasian Economic Union (EAEU), and their neighbors was the focus of the pilot phase of an IIASA project that concluded in 2016. The project, coordinated by the Advanced Systems Analysis Program, brought together an international group of economists, modelers, and other experts for constructive dialogue on the multiple facets of how such cooperation might work.

Relations between the EU and Russia would need to be much improved for the enhanced EU-EAEU economic cooperation to become a realistic proposition. However, setting aside the present political tensions, the IIASA project *Challenges and Opportunities of Economic Integration within a wider European and Eurasian Space* takes the standpoint that all sides would benefit from "Lisbon-to-Vladivostok" economic cooperation. To prepare for this, the project has brought together officials and experts to have a constructive dialogue about the opportunities and challenges of any economic partnership.

Many dimensions need to be considered, ranging from trade in goods and services to the free movement of capital and people, including facilitating visas and residence permits, the development of trans-border transport infrastructure, revised regulations for intellectual property rights, government procurement, and policies for state-owned companies.

The project identified several key facets that should be considered, including trade regimes and extending the deal beyond a traditional free-trade area; energy security; transport and infrastructure; and the mobility of people. Any research on this topic must go beyond estimating short-term, direct trade effects and extend to long-term, indirect effects, the project participants concluded. Especially those related to "non-tariff barriers"—such as sanitary or veterinary regulations and customs administration. These can have significant economic impacts and implications.

There is a fundamental reciprocal interest in energy security for the EU and EAEU. For the EU, this means supply security (source security, transit security, and fair and predictable prices); for Kazakhstan and Russia it is demand security (financial and economic security, and fair and predictable prices); and for transit countries it is the stability of revenues and supplies.

Transport networks (both road and railway) should be further developed in the near future, and the potential for common electric power markets, pipeline systems, and trans-continental fiber-optic links should also be explored. Adequate regulatory frameworks, security, and investments are key for both transport and infrastructure.

To ensure the mobility of business people, experts, and professionals, efficient visa and residence permit procedures are needed, along with the mutual recognition of qualifications. These steps can eventually lead to a visa-free regime with large-scale academic exchanges. However, the project participants do caution against prematurely raising the issue of the labor migration in the EU-EAEU context.

Another important topic discussed by project experts was the future of trade and economic relations between the EU, the EAEU, and Ukraine, Moldova, and Georgia—three states that have already concluded deep and comprehensive free trade agreements with the EU. The development of EU-EAEU relations will require constructive negotiations on a fair trade policy between Ukraine, Moldova, Georgia, and the EAEU, with the participation of the EU to ensure the compatibility of the EU-EAEU cooperation deals.

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Challenges and Opportunities of Economic Integration within a Wider European and Eurasian Space

Wildfires of the future

Wildfires have devastating effects across the globe, and as countries struggle to deal with their increased frequency under climate change, predicting their future impacts is crucial. To do this, researchers from the Tropical Futures Initiative adapted the IIASA wildfire model to Indonesia, adding the effect of burning peat and incorporating crowdsourced data on human activity.

Wildfires not only damage property and cause substantial air pollution, they also endanger lives and livelihoods. In Indonesia, fires affect millions of hectares of land, producing severe smoke haze pollution, and leading to CO_2 emissions comparable to the annual fossil fuel emissions of India.

Assessing the area of land burned is an important step in estimating the cost of wildfires to society, their effect on air quality, and the CO_2 emissions they might cause. The IIASA wildfire climate impacts and adaptation model (FLAM) has been developed to project future burned areas and to assess climate change impacts and adaptation options.

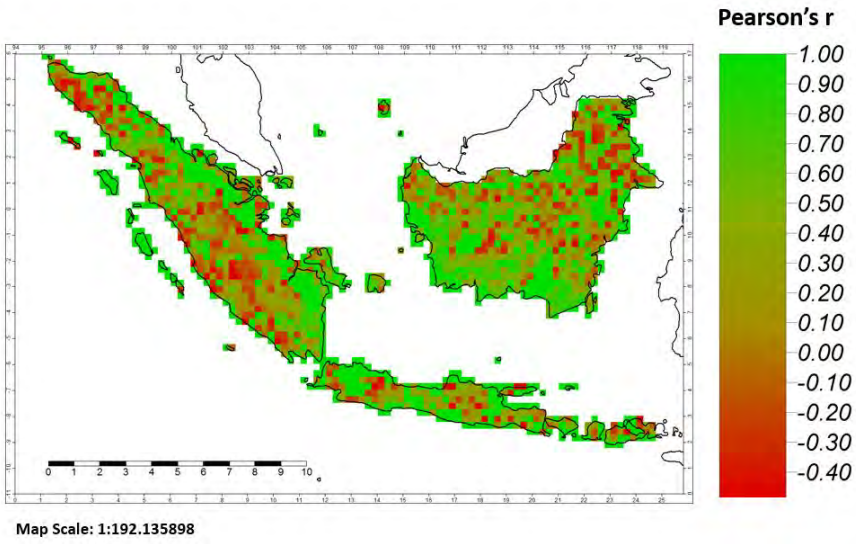
To do this, the model combines key information on climate, human activity, and fuel moisture and availability.

FLAM has previously been used to explore wildfires in Europe, and has performed well when compared with real historical data [1][2]. In the latest study, along with adapting the model for Indonesia, the researchers upgraded the model in several ways [3].

First, they included the impacts of burning peat as well as forests. Peatlands act as globally important carbon storage, and including them is crucial to understanding the true impacts of wildfires.

Second, the team developed a new approach for determining the probability that a fire would start .

Finally, the team improved the model's representation of human activity—which substantially increases the chances of wildfires—by using maps developed at IIASA based on data generated by citizen scientists searching satellite images for signs of human activity. When tested against real data collected in 2000-2008, the model showed satisfactory accuracy.



Spatial correlation between the FLAM model projections of yearly burned areas for the forest fires and real-world data for the period 2000-2008.

Futures initiatives

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Tropical Futures Initiative

Further information

The project *Delivering Incentives to End Deforestation: Global Ambition, Private/Public Finance, and Zero-Deforestation Supply Chains* is funded by the Norwegian Agency for Development Cooperation under agreement number QZA-0464 QZA-16/0218;

Research Program Future Forests, funded by the Swedish Foundation for Strategic Environmental Research.

Energy and landscape sustainability in Indonesia

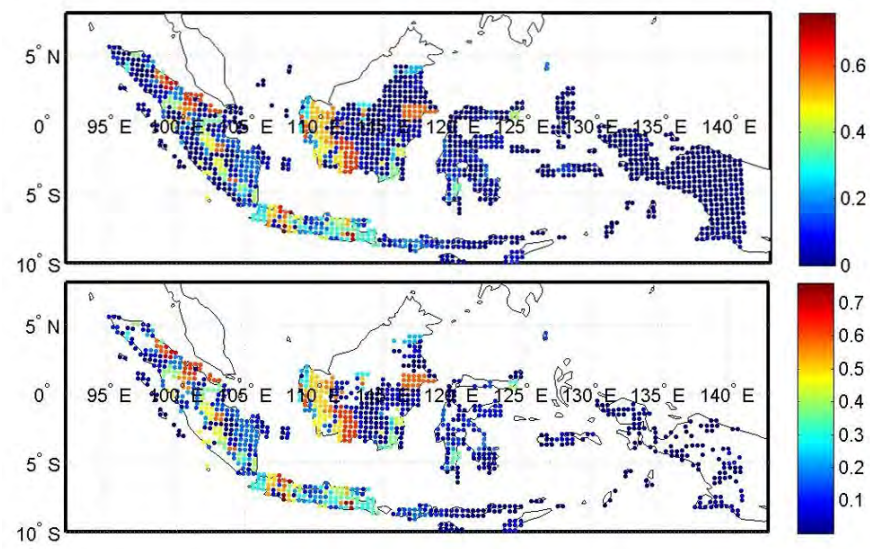
To support the government of Indonesia to plan a sustainable energy system, researchers and collaborators from the IIASA Tropical Futures Initiative developed a special version of the institute's BeWhere model. This will develop and assess an alternative energy network for the country, taking into account protection for its natural and cultural heritage.

As climate change progresses, the urgent need for an effective network of renewable energy producers grows. The IIASA BeWhere model tracks the costs and greenhouse gas emissions across every section of such a network. By testing different policy options at every step of the supply chain, the model identifies all possibilities for increasing efficiency and reducing costs and emissions. This provides valuable information on which technologies should be used; the resources needed to create the energy; the best locations for renewables; and the most efficient way to distribute energy to the consumers.

In 2016, researchers from the Tropical Futures Initiative adapted the model for Indonesia, considering renewable energy technologies—such as solar and geothermal—alongside existing coal plants, which could be adapted to burn a mix of coal and biomass.

Using the model, the team will identify an optimally adapted renewable energy mix for the country. To ensure holistic sustainability, the researchers will include nature protection and cultural heritage areas, where biomass harvesting and power plant sites will likely be limited—depending on the protection type and renewable energy technology.

For Indonesia to achieve its goal of having renewable energy make up a 23% share of the national energy mix by 2025, biomass for bioenergy is required from across the country, the model results show (top graph). When the model takes into account conservation areas, the picture is different, allowing decision makers to examine all aspects of sustainability policy (bottom picture).



Biomass use intensity for bioenergy production for 23% renewable energy contribution to the Indonesian energy mix considering all forest wood possibly available (top graph) and omitting the primitive forest (bottom graph).

This work is part of an online decision-support platform focusing on renewable energy development in Indonesia. The portal aims to be a one-stop shop for data on renewable energy resource availability, as well as providing user-friendly analysis tools that policymakers can use to make sound decisions.

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Tropical Futures Initiative

Collaborators

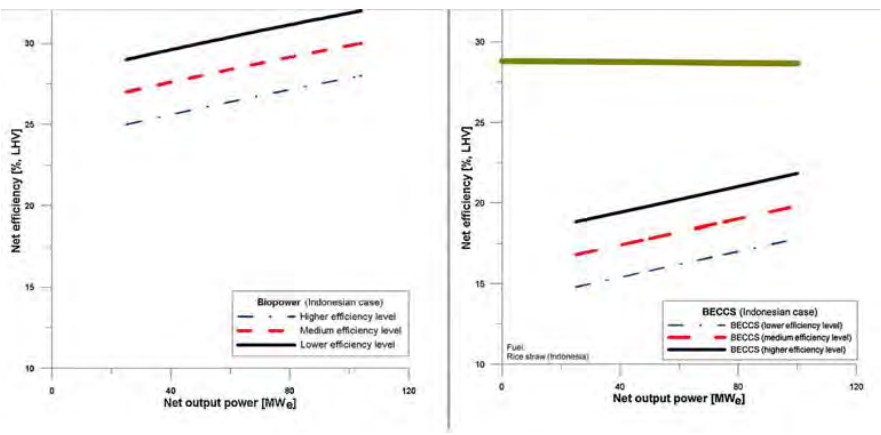
- World Resources Institute Indonesia
- Ministry of Energy and Mineral Resources of Indonesia

Negative emissions in the tropics

Many of the options proposed for achieving a stable climate rely on 'bioenergy with carbon capture and storage'— burning plant matter for energy, capturing the carbon, and storing it underground. Under the IIASA Tropical Futures Initiative, researchers explored optimal strategies for harnessing negative emissions in South East Asia—in particular Indonesia.

While there is a strong scientific consensus that we need to aggressively cut greenhouse gas emissions immediately, there is also growing evidence that we may not be able to achieve the necessary reductions in the time available. This means that we may need a way of removing CO_2 already in the atmosphere — a process known as negative emissions.

Negative emissions can come in many forms: from simply planting more trees, to crushing rocks that naturally absorb CO_2. One widely considered option is using plant matter as a fuel to produce energy, then capturing the CO_2 that is emitted and storing it underground. This is known as bioenergy with carbon capture and storage (BECCS).



Trajectories of biopower plant net efficiency without carbon capture and storage (left), and the resulting net efficiency of co-fired biomass and biopower with carbon capture and storage (BECCS, right) depending on plant size (net power output).

This latter technology is cited by research as being an important part of restricting warming to safe — or at least safer — levels since it contributes to both carbon sequestration and decarbonization of the energy system. In fact, more than half of the future scenarios that give at least a 66% chance of limiting warming to 2°C, which were developed for the Intergovernmental Panel on Climate Change (IPCC), feature BECCS.

A recent IIASA study addresses deployment of BECCS in Indonesia, examining whether adapting existing coal-fired power stations so that they can burn a mix of coal and plant waste from agriculture (such as seed kernels or stems that are usually discarded), is more effective than building specific biomass-burning power stations.

The team found that although both options saved the same amount of CO_2, the combined stations were more efficient, producing more electricity for the amount of biomass burnt. More efficiency means that burning biomass in adapted coal-fired power stations would be more economically viable.

It is also likely to be easier and cheaper to convert existing coal power stations than build new specific biomass-burning stations. With lower investments and existing infrastructure, policymakers and other stakeholders are more likely to embrace the idea.

There are limitations: for instance, the study results indicate that under the current conditions it is not possible to burn any more than 30% biomass in a combined power station. There are also uncertainties surrounding whether it is possible to collect enough biomass on the scale needed. However, the results are broadly general, and can be applied to other countries and situations, making them a valuable starting point.

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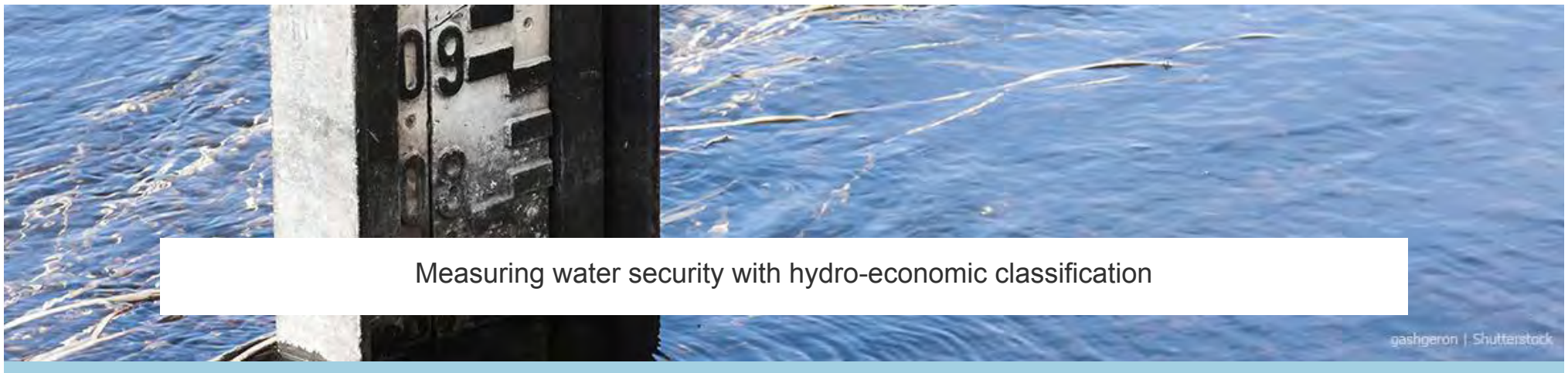
Tropical Futures Initiative

Collaborators

SINTEF Energy Research



Measuring water security with hydro-economic classification

A novel method to measure water security has been further developed by the IIASA Water Futures and Solutions Initiative. The hydro-economic classification uses two different dimensions to measure water security: the complexity of the hydrology and human water use, and the coping and adaptation capacity.

The IIASA-developed hydro-economic classification evaluates watersheds, countries, or regions using a combination of hydrological complexity and economic-institutional coping capacity [1]. In this way, it can identify vulnerable regions where the prevailing hydro-climatic conditions for human water use are complex and economic-institutional coping capacity is low.

Hydrological complexity is defined on the basis of four indicators:

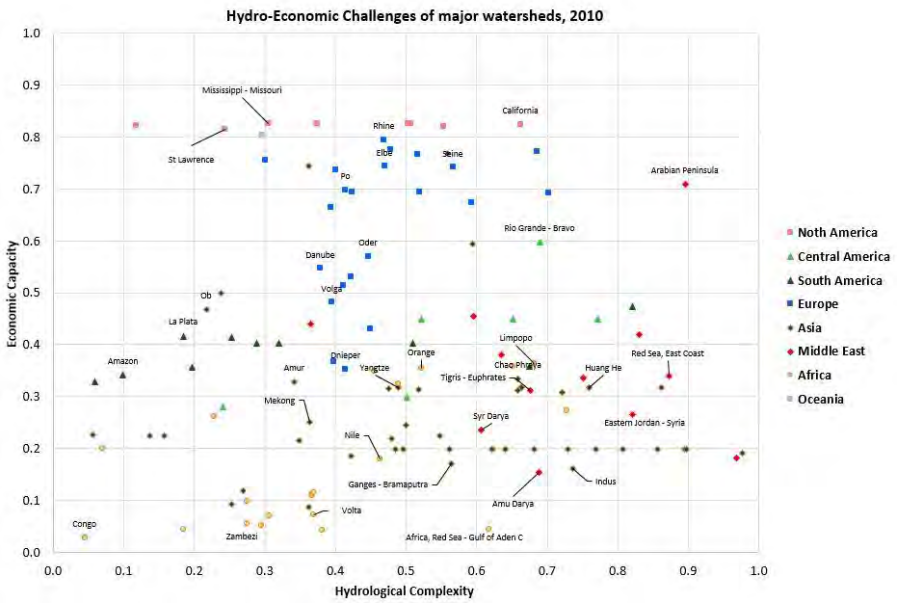
- A measure of water availability, defined as total renewable water resources per capita
- A measure of the relative intensity of water use, defined as the ratio of annual water withdrawal for agriculture, industry, and the domestic sector to the total renewable water resources
- The runoff variability, defined as the variation in monthly runoff for a 30-year period showing both inter- and intra-annual variability
- A measure of the dependency on external water resources, defined as the ratio of external (i.e. from outside national boundaries) water resources to total renewable water resources.

All four indicators were compiled based on data and model calculations consistent with the Representative Concentration Pathways (four greenhouse gas concentration trajectories), and the Shared Socioeconomic Pathways (five possible paths human societies could follow over the next century), which together provide the foundation for global climate modeling.

For economic-institutional coping capacity, researchers selected GDP per capita as a measure of economic strength and financial resources available for investing in risk reduction and adaptation. Although there are some exceptions, GDP per capita can also often provide a proxy for the availability and efficiency of institutions to cope with complex hydrological conditions.

The researchers are also discussing other potential indicators to be included in a measure of economic-institutional coping capacity. For example: education level [2], the Human Development Index, the Worldwide Governance Indicators, the Corruption Perception Index, and the Fragile State Index are all being considered.

The hydro-economic classification can group countries or watersheds into regions facing similar water security challenges and capacities. The Water Futures and Solutions Fast-Track scenario assessment [3] has applied this grouping method to differentiate key drivers of water demand and thereby go beyond globally uniform assumptions.



Watersheds with a population over 10 million people. Less water secure watersheds can be found in the lower right corner of the figure (e.g., Middle East and some Asian ones), while the upper left corner shows basins with higher water security (e.g., North American and European ones)

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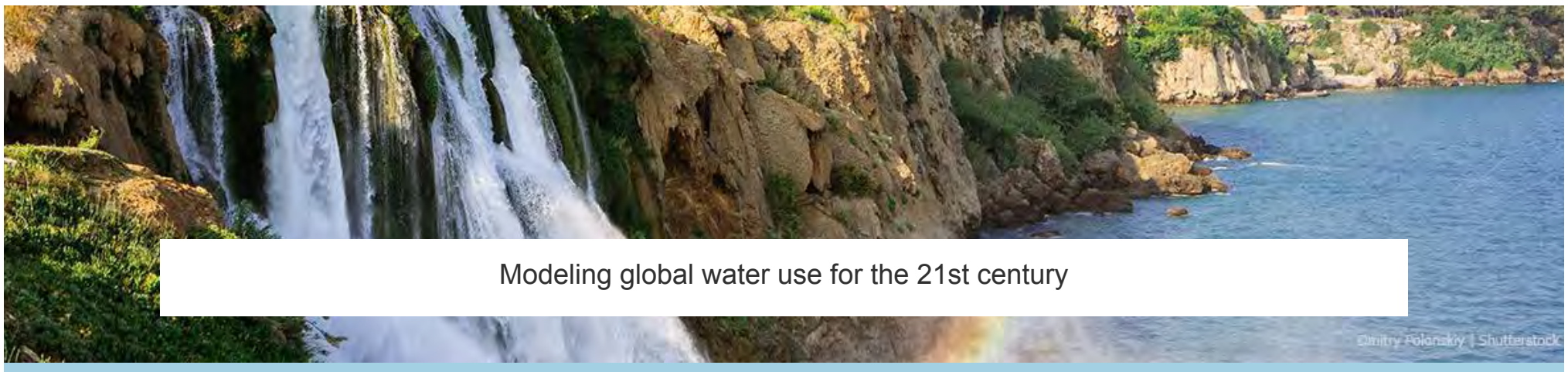
Water Futures and Solutions Initiative



Modeling global water use for the 21st century

The Community Water Model, developed by the IIASA Water Program, assesses water supply and demand at global and regional levels, and includes provision for healthy aquatic ecosystem. The hydrologic model is open source and can be linked to other models, enabling analysis of many different aspects of the water-energy-food-ecosystem nexus.

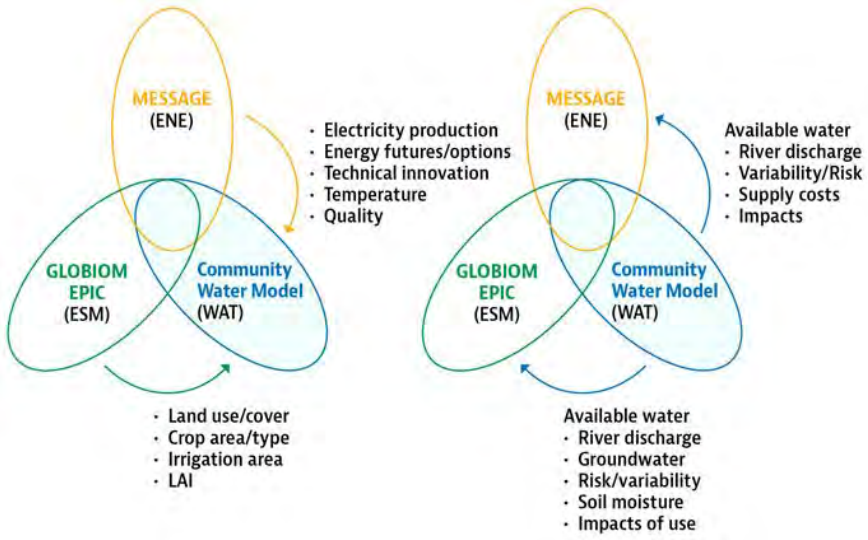
Rising population and growing economic development mean that water demand is expected to increase significantly, especially in developing regions. At the same time, climate change will have global, regional, and local impacts on water availability. Accurate assessment of water supply and demand is therefore vital, and must take into account both human water use and the amount needed to maintain healthy aquatic ecosystems. The Community Water Model will examine how future water demand will evolve in response to socioeconomic change and how water availability will change in response to climate.

The model has been developed to work at both global and regional levels at varying spatial resolutions, and the fact that it is open-source means that it provides a service to the water research and management community worldwide. In addition, it is flexible enough link to further planned developments such as water quality and hydro-economic extensions to the model.

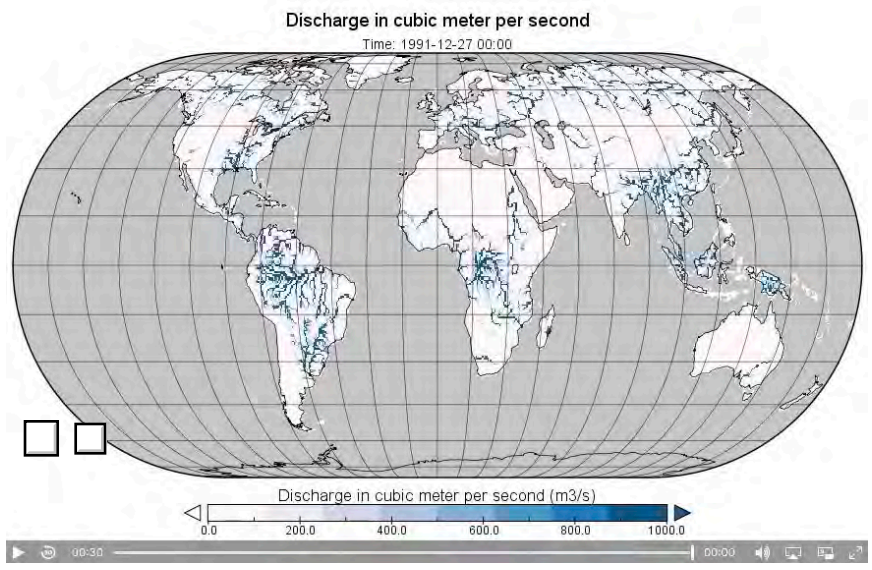
In this way, the model will provide a basis to develop a next-generation global hydro-economic modeling framework that can clarify the economic trade-offs among different water management options, encompassing both water supply infrastructure and demand management. The integrated modeling framework will consider water demand from agriculture, domestic, energy, industry, and the environment. It will also take into account the investment needed to alleviate future water scarcity, and provide a portfolio of economically optimal solutions. In addition, it will be able to track the energy requirements associated with the water supply system; for example, pumping, desalination, and interbasin transfer.

To achieve these goals, the model will be coupled to existing IIASA models, including the Model for Energy Supply Strategy Alternatives and their General Environmental Impact (MESSAGE); the Global Biosphere Management Model (GLOBIOM); and the Environmental Policy Integrated Model (EPIC).

In the short to medium term, the IIASA Water Program is working is to introduce water quality (e.g., salinization in deltas and eutrophication associated with mega cities) into the Community Water Model, and to consider qualitative and quantitative measures of transboundary river and groundwater governance



Linking models for best results. MESSAGE: Model for Energy Supply Strategy Alternatives and their General Environmental Impact from the IIASA Energy Program (ENE). GLOBIOM: Global Biosphere Management Model and EPIC: Environmental Policy Integrated Model from the IIASA Ecosystems Services and Management Program (ESM). Community Water Model from the IIASA Water Program (WAT).



The Community Water Model output, showing global discharge over a one year run example: 1/1/1991- 31/12/1992

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Water Program

Improving efficiency to meet agricultural water demand

Increased water-use efficiency in irrigation systems can cancel out the impact of the expected expansion of irrigation, new IIASA research has shown. The area of crops under irrigation is expected to rise in the coming decades; however, if irrigation efficiency is improved sufficiently net water demand need not increase.

Water security is under threat worldwide and effective, long-term water management strategies are urgently needed. The IIASA Water Future and Solutions Initiative aims to establish a comprehensive water assessment framework which covers agricultural, industrial, and domestic sectors [1]. In a recent study for the initiative, researchers projected the future trajectories of the key drivers of agricultural water demand: crop and irrigation area, and irrigation efficiency.

As a basis for the modeling the authors used three Shared Socioeconomic Pathways, which describe possible paths human societies could follow over the next century, along with the Representative Concentration Pathways, which are greenhouse gas concentration trajectories. Together, these pathways are used as the foundation for much of the world's global change modeling.

As food demand rises, crop area and irrigation area are both expected to expand, causing an increase in agricultural water demand. The IIASA Global Agro-ecological Zones system (GAEZ) provides projections of the spatial patterns that crop and irrigation areas will follow [2]. These projections take into account different climate scenarios; demographic and socioeconomic factors; production; consumption; and world food trade.

Although water demand is rising, economic and technological progress has the potential to improve water use efficiency. For this work researchers examined irrigation efficiency at a country level, considering all possible combinations of five crop types and three irrigation systems (gravity, sprinkler, and drip irrigation).

Efficiency increases when an existing irrigation system is replaced with an improved irrigation system of the same type, or another higher efficiency system, or when new areas are fitted with a high efficiency system. For this study, therefore, irrigation efficiency was defined as a function of replacement speed and irrigation area, and the researchers assumed that irrigation efficiency would increase with socioeconomic growth.

The GAEZ results indicate that the global area of irrigated land will be 10-15% larger by 2050. Under the sustainability scenario the area of land under irrigation would peak and decline after 2050, but the irrigated area is expected to keep expanding in the other two socioeconomic scenarios (Figure 1).

Irrigation efficiency is expected to steadily improve in all countries because of their economic growth. The biggest improvements were in China (0.6-1.5% efficiency gains per year), India (1.8-2.8% per year), Pakistan (2-3.4% per year), and the USA (0.6-1.7% per year). The results demonstrate that increased irrigation efficiency can cancel out the impact of irrigation area expansion on water demand (Figure 2).

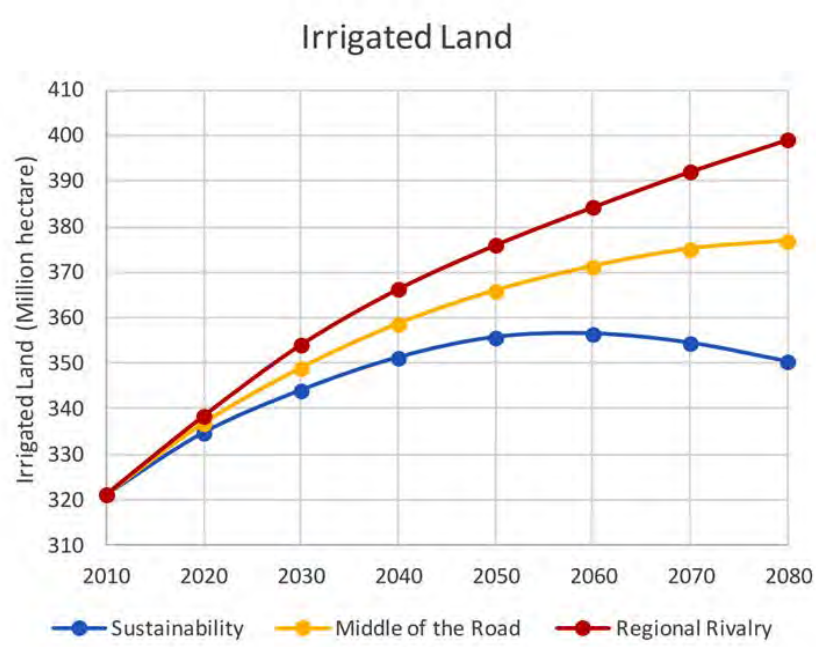

Figure 1. Projections of irrigation area expansion. (a) Projections for each scenarios. Sustainability scenario follows SSP1 (blue), Middle of the Road scenario follows SSP2 (yellow) and Regional Rivalry scenario follows SSP3 (Red).

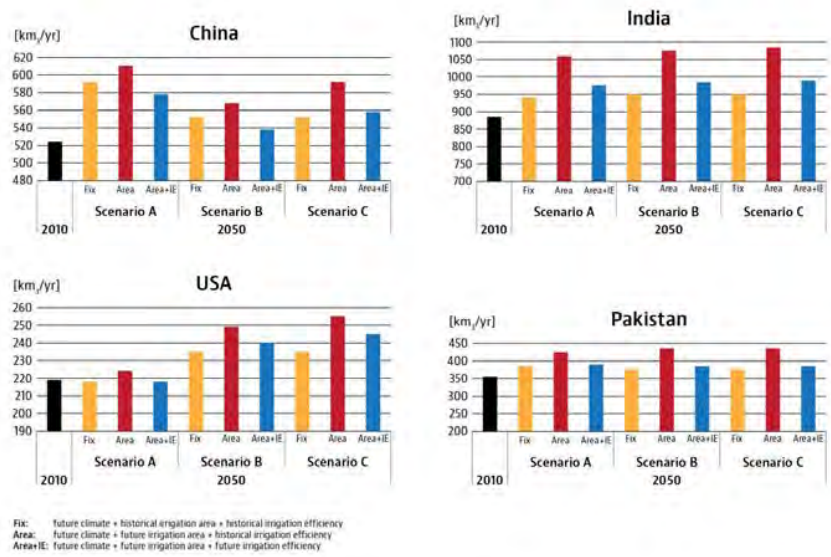

Figure 2. Change in irrigation water demand (in cubic kilometres) comparing 2010 and 2050 under three scenarios (Scenario A: socioeconomic pathway 1 with representative concentration pathway 4.5. Scenario B: socioeconomic pathway 2 with representative concentration pathway 6.0. Scenario C: socioeconomic pathway 3 with representative concentration pathway 6.0). Yellow bars consider only impact of climate change without irrigation area expansion or irrigation efficiency improvement. Red bars include impact of irrigation area expansion as well as climate change but without irrigation efficiency improvement. Blue bars take irrigation efficiency improvement into consideration as well as the other two impacts.

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Water Futures and Solutions Initiative

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Water security in Asia

The Asian Water Development Outlook report, published by the Asian Development Bank, provides an overview of the water security status of 48 countries of the Asian-Pacific regions. This critical report, which had substantial input from the IIASA Water Futures and Solutions Initiative, depicted possible Asian water futures, identified hotspots of water insecurity, and proposed solutions to cope with these threats.

To explore how water supply and demand will change in the decades to come, the IIASA Water Futures and Solutions Initiative developed a set of possible future scenarios for Asian-Pacific areas. These are based on the Shared Socioeconomic Pathways, which describe possible paths human societies could follow over the next century, along with the Representative Concentration Pathways, which are greenhouse gas concentration trajectories. These pathways were developed for the Intergovernmental Panel on Climate Change assessments and are used as the foundation for much of the world's global change modeling.

For the Asian Water Development Outlook 2016 report, three scenarios were explored:

- The sustainability scenario
- The middle of the road scenario
- The regional rivalry scenario

For the sustainability scenario, barriers to achieving sustainability, mitigation, and adaptation are minimal, in the middle of the Road scenario they are intemediate, and for regional rivalry they are high.

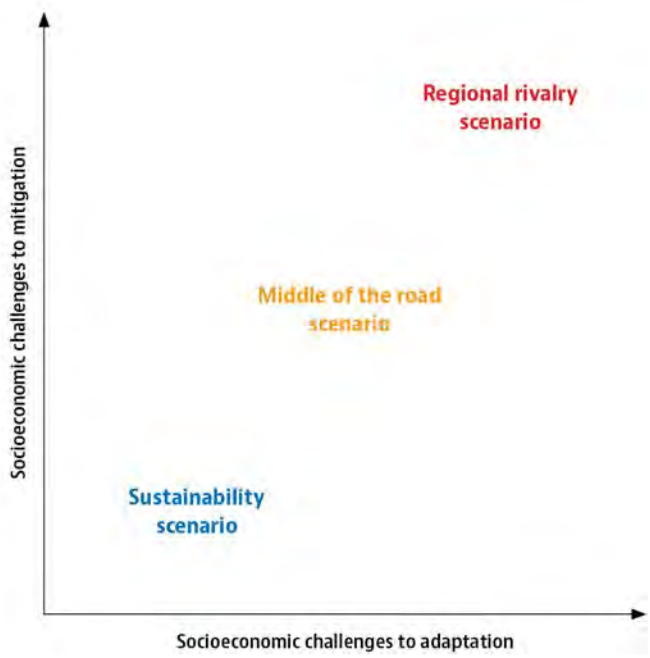

Figure 1: Scenario dimension for Asian-Pacific water futures.

The scenarios incorporate the considerable changes to Asia's population that are expected in the coming decades. Asia's total population was around 3.8 billion in 2010, and will grow to between 4.3 and 5.1 billion by the 2050s, depending on the scenario used. GDP per capita will increase in all combinations of scenarios and regions, however, total GDP may decrease in some regions such as East Asia and countries with advanced economies, all of which have implications for water use and demand.

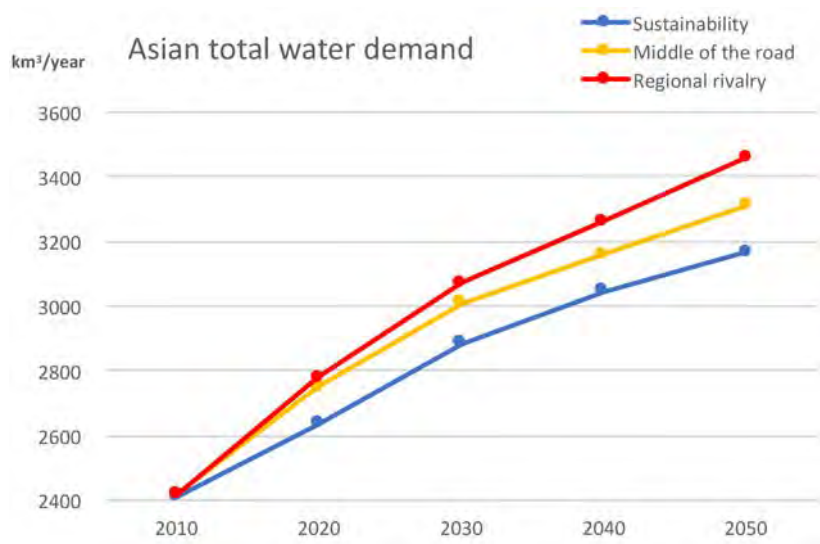

Figure 2: Total Asian-Pacific water demand projection

This study also assessed imbalance between water demand and supply, highlighting hotspots of water scarcity. Many countries in Asia, including, Afghanistan, Armenia, China, Pakistan, and Uzbekistan already experience pervasive water scarcity conditions. At present, almost all countries in central and West Asia, East Asia, South Asia, and parts of Southeast Asia have regions that suffer from severe water scarcity for at least one month every year.

Future projections indicate that the areas under severe water scarcity conditions in Asia will grow, especially in regions that are already hotspots for water scarcity, creating greater imbalances. Under all scenarios the number of people living in severely water scarce areas will increase from 1.2 billion to 1.7–2.1 billion, approximately 40% of Asia's future population. The largest share of affected people will be mainly in South Asia, followed by East Asia.

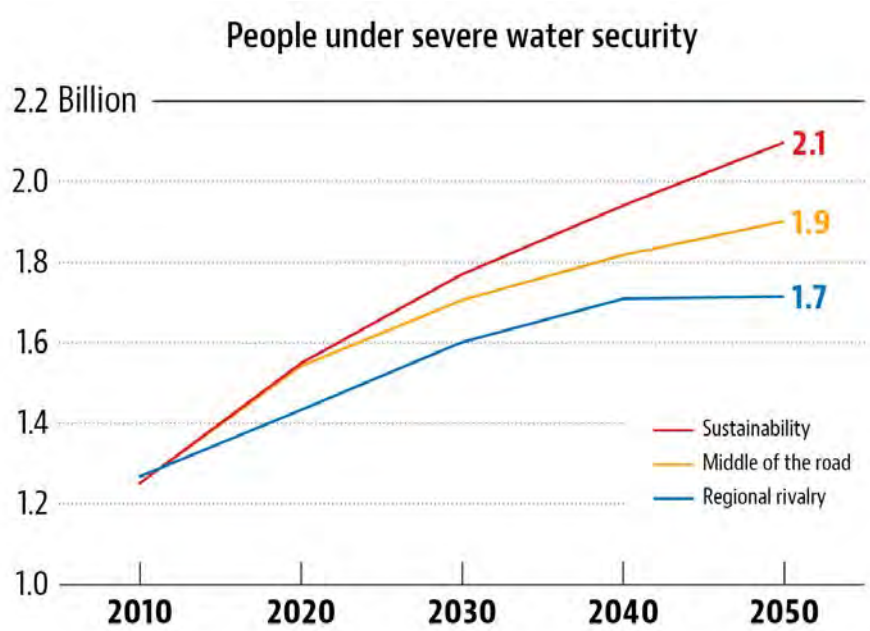

Figure 3: Asian-Pacific future population living in severe water scarce areas

Three state-of-the-art water models were used to calculate water demand for the agricultural, industrial, and domestic sectors, based on socioeconomic and climate changes. The researchers estimated that current Asian water demand (2,410 km^3/year) would rise by about 30–40% to 3,170-3,460 km^3/year in the 2050s under the three scenarios considered. At the regional scale, South Asia and East Asia remain the largest water users in the continent in all sectors until 2050, and significant rises in agricultural demand are also expected in Central and West Asia.

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Water Futures and Solutions Initiative

Collaborators

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Integrated projects to support global transformations

CD-LINKS

The Linking Climate and Development Policies – Leveraging International Networks and Knowledge Sharing (CD–LINKS) project aims to develop pathways to show how climate change mitigation could be integrated into sustainable development, and what synergies or trade–offs might arise.

Project website

Energy and the Sustainable Development Goals

IS-WEL

The Integrated Solutions for Water, Energy, and Land partnership (IS-WEL) develops coherent strategies for a future where climate change, economic development, and population growth are all expected to put increasing pressure on these key resources.

Project website

Sustainable use of water, energy, and land

Supporting sustainable water policy

The World in 2050

The World in 2050 (TWI2050) project explores how all 17 UN Sustainable Development Goals can be achieved in all parts of the world, and seeks to develop a robust understanding of how modern technologies can support sustainable development.

Project website

The World in 2050

Energy and the Sustainable Development Goals

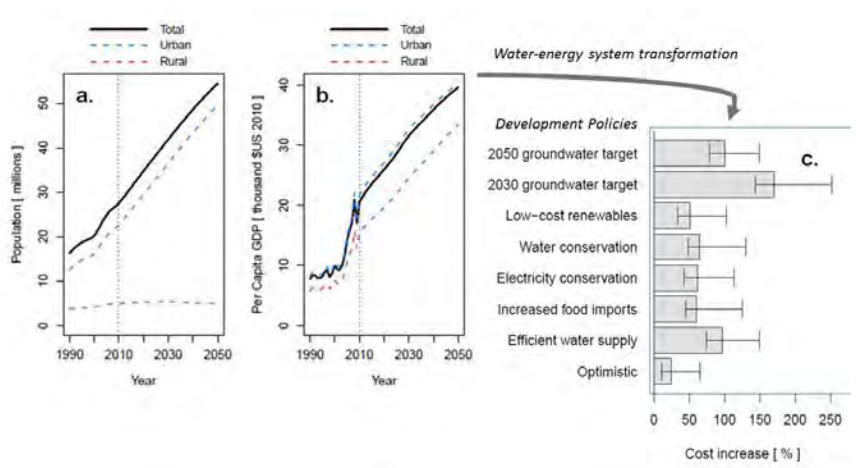
In exploring the complex interplay between climate action and sustainable development, the IIASA Energy Program (ENE) has assessed what makes climate policies effective. Specifically the researchers have explored the interaction of climate policy with a host of other policy objectives, including the implications for water and energy security.

Designing effective policy is crucial if we are to avoid catastrophic climate change. To determine what works, researchers from the *Linking Climate and Development – Leveraging International Networks and Knowledge Sharing* (CD-LINKS) project examined 19 case studies. Barriers to policy success included a lack of money and required infrastructure, or contractual challenges when many parties needed to establish business relations. When it came to the interaction of climate and sustainable development, many cases—especially those in developing countries—showed that other aspects of sustainability, such as reducing air pollution, were the drivers behind policies and climate mitigation was essentially a co-benefit.

Through collaboration with international modeling teams (in Brazil, China, the EU, India, Japan, Russia, and the USA) the CD-LINKS project has also developed transformation pathways that coincide with national contexts but at the same time are consistent with the Paris Agreement objectives of limiting temperature change to 1.5-2°C.

Limiting temperature change in this way will require a transformation of the global energy system. However, different climate-friendly energy technologies require varying amounts of water, and therefore such a transition could have a substantial impact on water demand. To examine these impacts, ENE enhanced the Model for Energy Supply Strategy Alternatives and their General Environmental Impact (MESSAGE) to account for energy-related water use. After applying the model to a range of scenarios, all of which would ensure a 2°C limit [1], the researchers demonstrated that strategies combining improved energy efficiency with a rapid scale-up of solar and wind power generation can yield climate stabilization, reduced water demand, and improved water quality.

A case study on the Kingdom of Saudi Arabia illustrated the critical need of balancing water use and climate objectives on the national level. In Saudi Arabia, a transition away from groundwater use by the year 2050 could increase national electricity demands by more than 40% relative to 2010 conditions. Simon Parkinson and colleagues conclude that the increase in energy demand would be primarily due to the expansion of energy-intensive desalination and water conveyance [2][3].

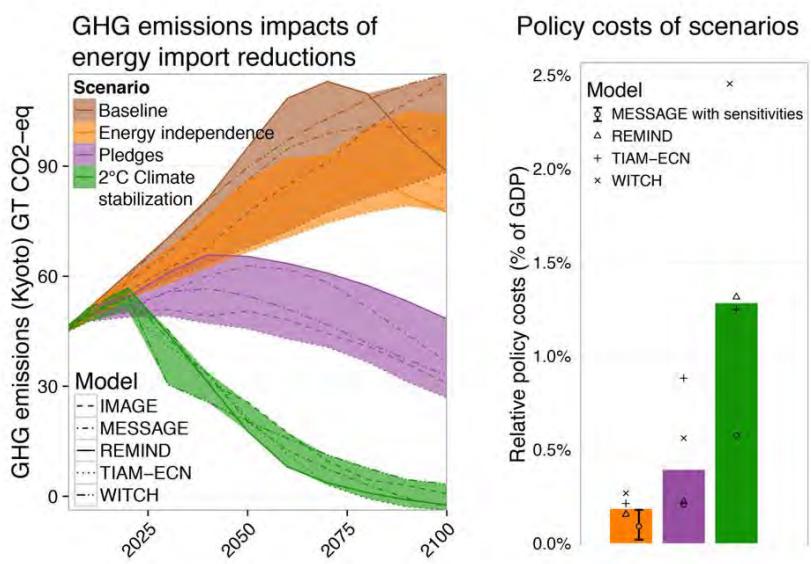


Economic impacts of combined climate and groundwater policies in Saudi Arabia. a. Population to 2050; b. Income to 2050; c. Cost for combined water-energy system development relative to a case no groundwater or climate targets [2].

Another study examined the impact of energy imports on greenhouse gas emissions. While it has been established that energy imports would fall if greenhouse gas emissions were reduced, the team wanted to know if emissions fall when energy imports are restricted.

The results showed that while emissions reductions generally benefit energy security—by reducing energy imports—policies focusing on energy security do not show the same co-benefits for climate targets. In fact, policies to reduce energy imports would only lower emissions enough to limit warming to roughly 3.5°C to 4°C.

The study also compared the relative costs of energy independence and climate policies. Reducing energy imports would cost between 3 and 20 times less than stabilizing climate change at 2°C by 2100, but would be comparable to the cost of the climate pledges. Thus, while climate policies can lead to lower energy imports, these can be reduced more cheaply through energy import restrictions.



The impacts of energy import restrictions on greenhouse gas emissions and the relative costs of energy independence and climate policies.

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Energy Program

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- Potsdam Institute for Climate Impact Research, Germany
- Energy research Centre of the Netherlands
- PBL Netherlands Environmental Assessment Agency
- University of Utrecht, Netherlands
- Central European University
- Euro-Mediterranean Center on Climate Change, Italy
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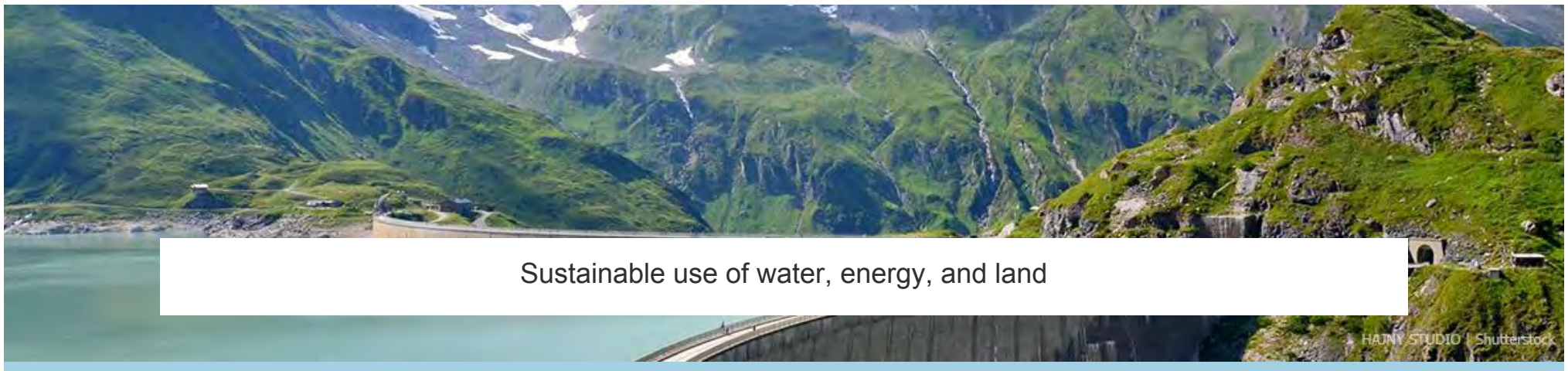
- Research Institute of Innovative Technology for the Earth, Japan
- Pacific Northwest National Laboratory, USA
- Korea Advanced Institute of Science and Technology, Republic of Korea
- European Commission Joint Research Centre



Sustainable use of water, energy, and land

The Integrated Solutions for Water, Energy, and Land (IS-WEL) project is developing a tool to assess these three resources, and demand for them, around the world. By incorporating the interlinkages among the resources, the project will support decision makers in developing robust, sustainable policies. The Indus and Zambezi river basins will form the first two case studies for the tool.

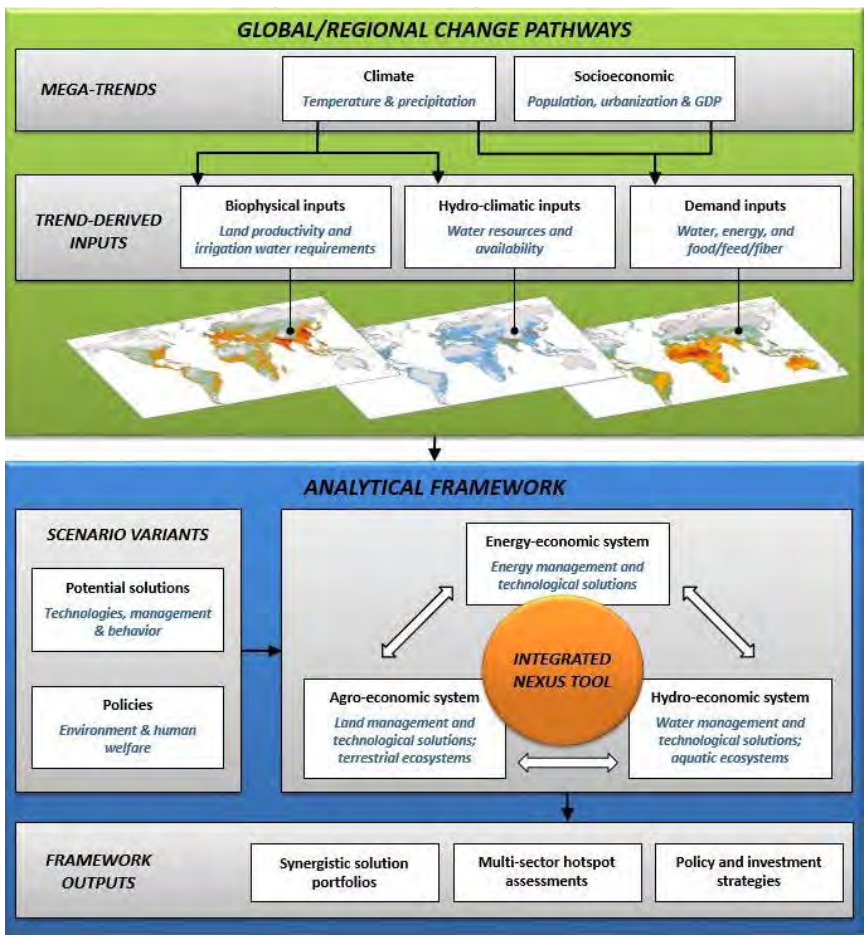
Demand for water, energy, and food—the mainstays of life—is rapidly rising around the world. This is particularly true in the Global South, which also includes the regions that are most vulnerable to climate change. Considering the interlinkages among the three resources is vital, because policies designed without such knowledge can cause food crises and environmental degradation.

The IS-WEL project aims develop an integrated assessment framework that can support long-term and sustainable planning for water, energy, and food resources at global to regional scales. It will also identify hotspots of demand and provide cost-effective interventions. Importantly, the project will work in an inclusive way, engaging relevant stakeholders, decision makers, and investors to co-develop solutions for meeting sustainable development goals.

Although there has been some success in linking models of different sectors, a new review by IS-WEL researchers shows that the development of frameworks capable of assessing the intersection of all three resources has been limited, and there is substantial scope for improvement [1]. The study also highlights existing knowledge gaps and opportunities for future research, including:

- the need to develop assessment frameworks based on consistent and regionally-transferable platforms that can be used at different spatial scales;
- the lack of spatially-explicit techno-economic models, particularly for the energy and water sectors;
- the need to have an improved representation of nexus impacts on environmental quality and of implementation challenges related to limited financial and institutional capacity;
- an improved tracking of energy and land requirements across sectors;
- improved representation of the role of distribution infrastructure in alleviating resource challenges; and
- a dynamic multi-sectoral hotspot assessment.

In 2016 the first scientific papers from the project, analyzing a variety of resource interactions, constraints, and potential synergies, were published [2][3][4][5][6][7][8]. The IIASA Transitions to New Technologies Program also recruited a new research scholar who will contribute to IS-WEL research through a multi-dimensional technology assessment of nexus technologies.



To accomplish IS-WEL's ambitious goals, a major alliance has been built across the Energy, Transitions to New Technologies, Water, and Ecosystems Services and Management programs at IIASA. This cooperation will link traditionally separate resource management models of water, energy, and land use into a next-generation integrated systems analysis framework.

IS-WEL

Collaborators

- UN Industrial Development Organization
- Global Environmental Facility

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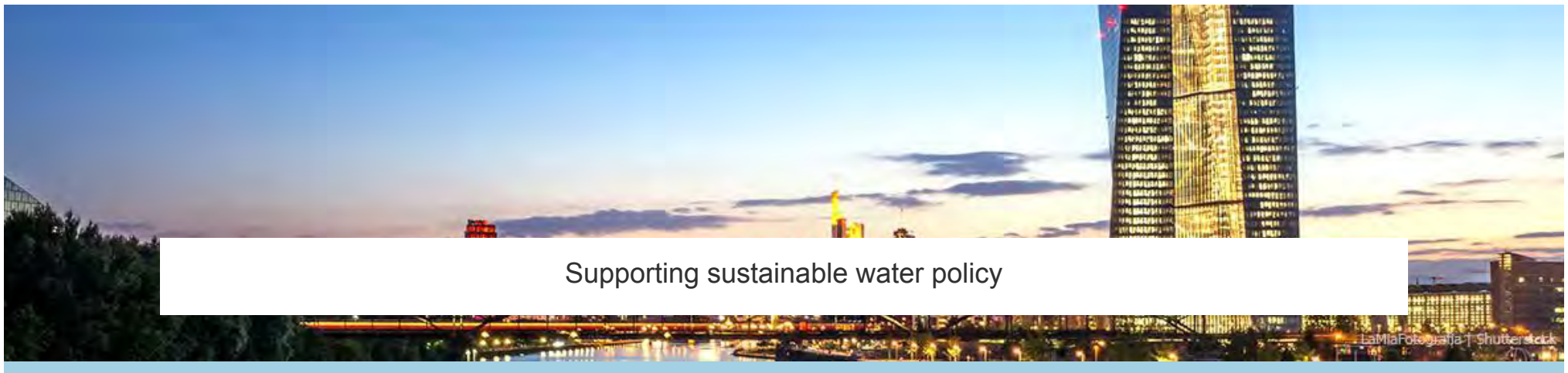


Supporting sustainable water policy

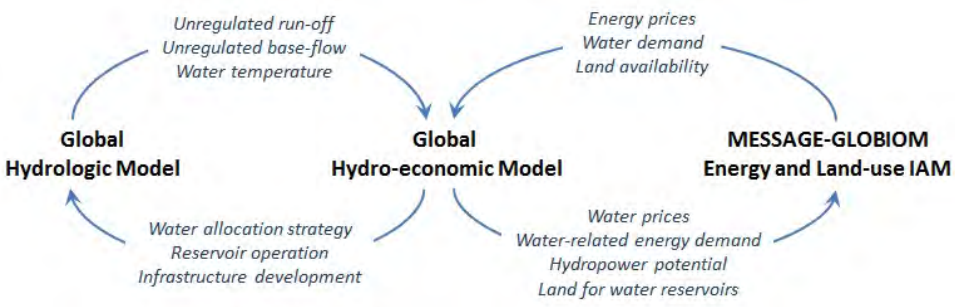
Climate change and growing demand mean that competition for scarce water resources is increasing worldwide. The consequences for the environment and the global economy could be severe. The Global Hydro-economic Model, currently under development by the IIASA Water Program, can be used to simulate a wide range of possible future scenarios, supporting policymakers to create cost-effective, long-term sustainable water management policies.

The pressure on water resources has been mounting worldwide, with water scarcity becoming a widespread problem in most arid and semiarid regions around the world. Global water extractions have increased more than six fold in the last century, which is more than twice the rate of human population growth [1]. However, the impact of growing water scarcity on long-term sustainable development has not been adequately addressed by the integrated assessment research community.

Specifically, the allocation of water resources across regions and sectors at the global level remains largely unaccounted for in long-term modeling. To reconcile potential inconsistencies introduced by constraints on future water availability, IIASA researchers are developing the Global Hydro-economic Model, which will integrate spatially distributed water resource systems, infrastructure, management options, and economic values. In addition, it will be possible to link it with other IIASA integrated assessment models: the Community Water Model; the Model for Energy Supply Strategy Alternatives and their General Environmental Impact; and the Global Biosphere Management Model.

The Global Hydro-economic Model uses optimization to balance global water demand and supply at the level of large-scale river basins. The technique allows the model to minimize the total costs of meeting the water demands from the agricultural, industrial (energy and manufacturing), and domestic sectors, while also taking into account various resource, institutional, and environmental constraints, such as retaining enough water for healthy aquatic ecosystems.

Monthly variation will be included so the model can align with existing IIASA integrated assessment models. The model can be used to simulate a variety of basin management decisions including resource extractions, interbasin transfers, reservoir storage, and water infrastructure investment (i.e., the choice of the size and location of new water projects). The model uses information on water demand and availability provided by existing global integrated assessment models at IIASA and provides information on water resources development and allocation to those models.



The proposed integration of the Global Hydro-economic Model with other IIASA integrated assessment tools.

The development of the Global Hydro-economic Model, which involves several different programs at IIASA (the Water, Energy, and Ecosystem Services and Management programs) is carried out as part of the larger *Integrated Solutions for Water, Energy, and Land* project.

Integrated projects

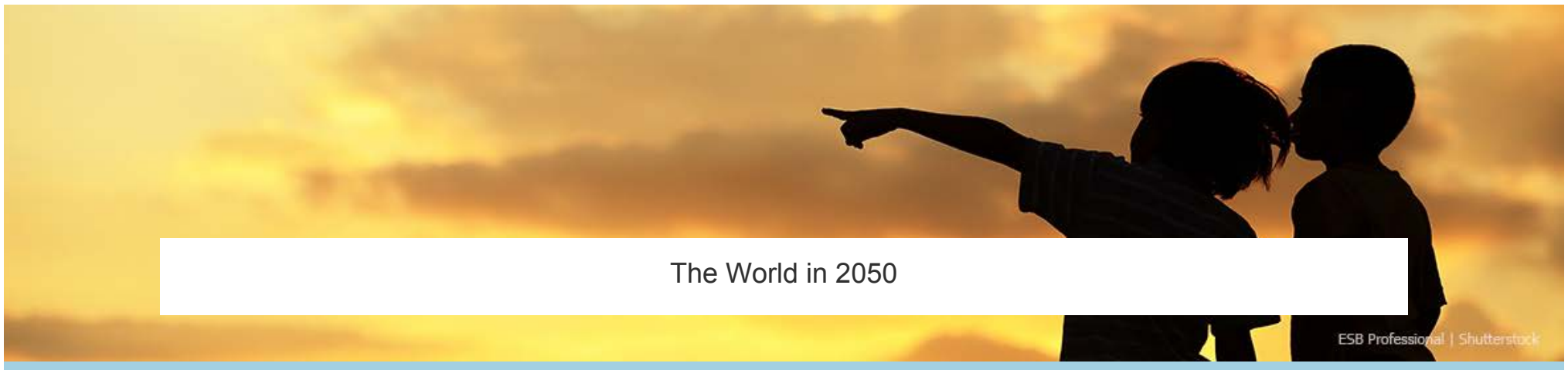
References

[1] Wada Y, Flörke M, Hanasaki N, Eisner S, Fischer G, Tramberend S, Satoh Y, van Vliet M, et al. (2016). Modeling global water use for the 21st century: Water Futures and Solutions (WFaS) initiative and its approaches. *Geoscientific Model Development* 9: 175-222.

[2] Kahil MT, Ward F A, Albiac J, Eggleston J, & Sanz D (2016). Hydro-economic modeling with aquifer-river interactions to guide sustainable basin management. *Journal of Hydrology* 539: 510-524.

[3] Kahil TM, Ward FA, Albiac J, Eggleston J, & Sanz D (2016). Hydro-economic modeling of conjunctive ground and surface water use to guide sustainable basin management. In: *European Geosciences Union (EGU) General Assembly 2016*, 17–22 April 2016, Vienna, Austria.

Water Program



The World in 2050

Achieving all 17 of the UN Sustainable Development Goals (SDGs) is a mammoth task that will require a strong scientific basis. The World in 2050 (TWI2050) project is aiming to understand how to achieve inclusive economic and social development within planetary boundaries, the benefits of achieving this, as well as the costs of inaction.

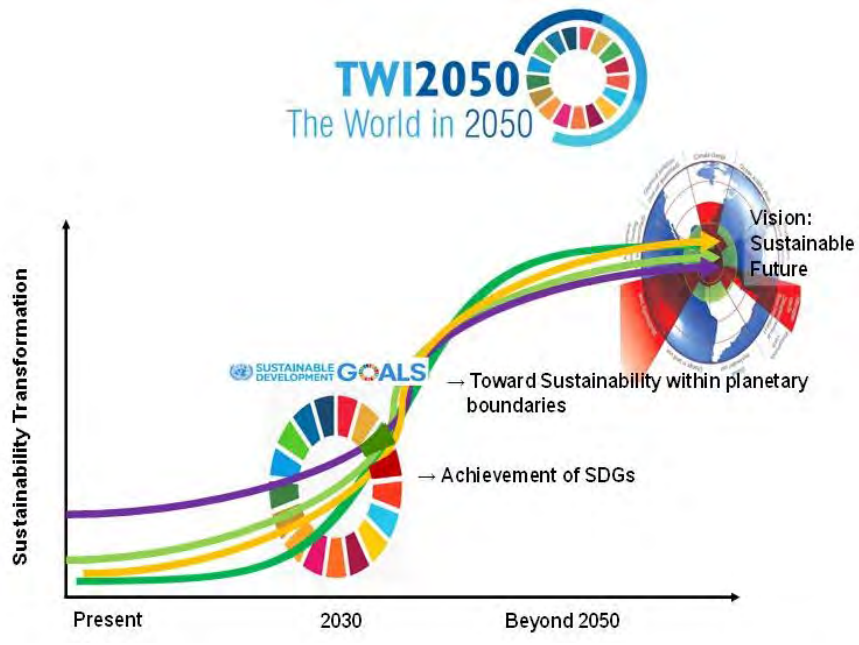
Using a systems approach, TWI2050 will provide science and policy advice for achieving the SDGs in an integrated manner so as to avoid potential conflicts among the 17 goals and reap the benefits of potential synergies.

TWI2050, launched by IIASA, the Sustainable Development Solutions Network, the Stockholm Resilience Center, and the Earth Institute at Columbia University, brings together leading modeling and analytical teams from around the world, including major policy institutions. Under the leadership of IIASA Deputy Director Nebojsa Nakicenovic, researcher in the Transitions to New Technologies Program, the TWI2050 secretariat has been established, with several researchers and a program officer hired in 2016 to join the project.

Technological innovation is of critical importance in achieving the SDGs, and sustainable development beyond 2030 requires a corresponding policy outreach at the highest international level. Recognizing the important contributions of IIASA to all of these factors, the UN Secretary-General appointed Nebojsa Nakicenovic to his special advisory 10-member group to support the Technology Facilitation Mechanism of the SDGs.

The first TWI2050 working meeting, bringing together all major analytical teams, took place in March 2016 at IIASA.

It is vital to understand the connections between the short-term (2030, the timeframe of the SDGs), medium-term (2050, the focus of TWI2050), and the long-term (2100 and beyond, the focus of climate research) dimensions of sustainable development.



Alternative sustainable development pathways that reach all 17 SDGs and the transformation toward sustainability within planetary boundaries beyond 2050. Source: (WBGU 2011).

A framing paper on these links was published in 2016 by Transition to New Technologies researchers, providing critical context for TWI2050 [1]. Important synergies can also be found in the related work of the German Advisory Panel of Global Change (WBGU), on which Neboijsa Nakicenovic served as member from 2010-2016.

References

[1] Nakicenovic N, Rockström J, Gaffney O, & Zimm C (2016). Global Commons in the Anthropocene: World Development on a Stable and Resilient Planet. IIASA Working Paper. IIASA, Laxenburg, Austria: WP-16-019.

Transitions to New Technologies Program

Funding partners

- Sustainable Development Solutions Network
- Stockholm Resilience Center, Sweden Earth
- Institute at Columbia University, USA

For a full list of collaborators, which is being continuously extended see:
www.twi2050.org

Governance and compliance

IIASA was established in 1972 as a non-governmental, international, autonomous scientific institution with headquarters in Laxenburg, Lower Austria. The objectives, governance, and activities of IIASA are laid out in the institute's Charter. Careful compliance with robust policy guides the institute's progress.

Governance
Financials

Health, safety, and wellbeing

Our people

Publications and open access

Environmental performance

In 2012, a group of volunteers at IIASA—the footprinters—conducted a review of the environmental and sustainability targets at IIASA. The group, a dedicated team of scientists involved in footprint assessment activities, aimed to identify ways to reduce the environmental impact of IIASA, through finding alternative technical and management solutions for sustainability in general and reducing greenhouse gas emissions in particular. The group was established in 2005 and had produced two previous greenhouse gas inventories in 2005 and 2008.

The 2012 report showed that IIASA activities in 2010 had resulted in about 2000 tons of CO2 equivalent, with business travel accounting for about half, followed by heating (27%) and staff commute (10%). Consumption of food and new computers accounted for about 5% together. Following this report, IIASA switched its electricity supply to 100% renewable sources, and hence reduced its footprint by approximately 140 tons CO2 equivalent annually. The footprinters also came up with a number of other recommendations of actions that could be taken to further reduce the environmental impact of IIASA activities.

Because of the nature of IIASA work, a typical researcher is involved in multiple project activities and travels extensively. The amount of business travel increases exponentially for program directors and the Directorate. In 2010 IIASA offset its air travel emissions by carbon credits, and for the 2012 conference IIASA bought emission certificates from the European Carbon Emission Trading System. IIASA additionally invested in an afforestation and development project in Uganda certified to the Carbon Fix Standard in 2012 (to offset IIASA activities in 2010). In 2010, low carbon meals were introduced at the IIASA restaurant, and a detailed analysis of business travel and travelers' attitudes was conducted. As a consequence of the business travel analysis, video- and web-conferencing equipment at IIASA was upgraded.

Since the 2012 report IIASA has experienced substantial growth and expansion of activities. In 2010 IIASA employed 209 researchers who made 908 business trips, compared to 348 staff in 2016 who made 1,345 business trips. The total flight distance in 2010 was 3.2 million kilometers, growing by over 40% to 4.6 million kilometers in 2016.

This expansion has required a substantial remodeling of IIASA infrastructure and facilities over recent years. The Directorate recognizes the need to work on a proposal for improving the institute's environmental impact. Therefore, in 2017 IIASA will start to devise operational sustainability targets and policies for the future.

Legal compliance

IIASA is legally registered as "Verein" (Association) in Austria with registration number (ZVR-Nr 524808900) and it is subject to the laws and jurisdiction of its host country, Austria. These include all laws typically impacting an organization of similar size., such as:

- IIASA as a "Verein": Austrian Association Act
- IIASA as an organization with an annual income over €20 million: Austrian Commercial Law
- IIASA as an employer: Austrian Labor Law; Austrian Health and Safety Acts and regulations; Austrian Social Insurance Law including specific agreements for IIASA – see Human resource policy and compliance section) etc.
- IIASA as a publisher and provider of research material: Austrian Media Act; Austrian E-Commerce Act; Austrian Copyright Law; Austrian Intellectual Property Law
- IIASA as a holder of information about people: Austrian Privacy Law; Austrian Data Protection Act

Copyright and data policies

Intellectual property and copyright

IIASA follows the rules and procedures laid out in the institute's Patent and Software policies. The Patent Policy ensures that any invention made in the course of the research activities at IIASA is used to bring about the widest possible benefits; that the institute gains financially from any commercial exploitation of patents resulting from the use of its resources; and that favorable terms shall be applied in granting licenses to organizations and citizens of NMO countries. The Software Policy defines and protects the intellectual property rights for software that has been developed by IIASA staff, and outlines the processes for commercialization, licensing, and distribution.

IIASA follows the rules and procedures laid out in the institute's Copyright Policy. This takes into consideration the practices of international journals and publishers, and is designed to facilitate the widest possible dissemination of IIASA results.

Data protection and privacy

As a publisher and provider of research material, IIASA observes the Austrian Media Act; Austrian E-Commerce Act; Austrian Copyright Law; and Austrian Intellectual Property Law. The institute holds a range of information on over 18,500 individuals that have some connection with IIASA and it also mass mails some of these contacts for various purposes, ranging from asking them to attend an event to encouraging them to use IIASA research. The institute therefore observes the Austrian Privacy Law, the Austrian Data Protection Act, and the Austrian Telecommunications Act. In 2016 as part of the roll out of the institute's new central contact database, it developed a Contact Relationship Management Policy and appropriate training to ensure that all IIASA staff who use the contact database are informed and follow best practices and Austrian law regarding the use of this information.

Data management and archive

The IIASA rules laid out in its policies on Good Scientific Practice and Conflict of Interest provides the institute's current data archiving standard, which is intended to comply with the expectations of most funders. This ensures that for experimental work, an exact documentation of scientific procedure and results is mandatory, since the reproducibility of results is a fundamental feature of such research. Primary data is secured and stored for a duration of ten years. For model-based work, model specifications and methods of analysis have to be sufficiently documented, ideally in a peer-reviewed publication or its official supplement.

Governance

External Governance

Membership of IIASA

According to the Charter, membership of IIASA is open to one professional institution from any country as long as it represents the relevant scholarly community of the country, subscribes to the IIASA Charter, and meets the financial obligations of membership. IIASA Council votes on each country's application to join IIASA and also on whether to discontinue a country's membership.

In June 2016, the IIASA council agreed to accept Iran as a new member country, represented by the Iran National Science Foundation as the National Member Organization (NMO). It also accepted the request from Pakistan to change their membership status to observer, taking with effect from 1 Jan 2017. The council also reviewed the IIASA membership strategy and discussed and agreed on new countries to target for membership.

National Member Organizations

Each IIASA member country designates a NMO to represent the nation's scholarly community and act as a bridge to link their research and policy communities to IIASA. The NMOs are one of three types: national academies, government research funding agencies, or autonomous organizations or committees. Through its NMO each member country has two main roles: (1) governance of IIASA through its representative Council Member for IIASA and (2) acting as a bridge between IIASA and national stakeholders.

In June 2016, the IIASA Council approved the transfer of membership in Brazil to the Brazilian Federal Agency for Support and Evaluation of Graduate Education (CAPES). Most of the NMOs have National Committees to assist in the responsibilities of IIASA membership. The size of the committees range from 8 to 31, and members are generally chosen because of their expertise in relevant fields of research, because they are representatives of interested institutions, or because they have experience of IIASA.

IIASA NMOs and Council Members

On 31 December 2016 IIASA had 24 member countries, represented by the following NMOs:

AUSTRALIA The Commonwealth Scientific and Industrial Research Organisation (CSIRO)
Council Member: Dr. Peter Mayfield

AUSTRIA The Austrian Academy of Sciences (OEAW)
Council Member: Professor Dr. Gerhard Glatzel

BRAZIL The Brazilian Federal Agency for Support and Evaluation of Graduate Education (CAPES)
Council Member: Professor Concepta (Connie) McManus Pimentel

CHINA National Natural Science Foundation of China (NSFC)
Council Member: Professor Congqiang Liu

EGYPT Academy of Scientific Research and Technology (ASRT)
Council Member: Professor Mahmoud M. Sakr

FINLAND The Finnish Committee for IIASA
Council Member: Dr. Lea Kauppi

GERMANY Association for the Advancement of IIASA
Council Member: Professor Dr. Helga Weisz

INDIA Technology Information, Forecasting and Assessment Council (TIFAC)
Council Member: Professor Prabhat Ranjan

INDONESIA Indonesian National Committee for IIASA
Council Member: Professor Dr. Kuntoro Mangkusubroto

IRAN Iran National Science Foundation (INSF)
Council Member: Professor Nosratollah Zargham

JAPAN The Japan Committee for IIASA
Council Member: Professor Dr. Kazu Takemoto

KOREA, REPUBLIC OF National Research Foundation of Korea (NRF) Council Member: Dr. Moo Je Cho

MALAYSIA Academy of Sciences Malaysia (ASM)
Council Member: Professor Datuk Dr. Asma Ismail

MEXICO Mexican National Committee for IIASA
Council Member: Dr. Julio A. Santaella Castell and Dr. Enrique Cabrero Mendoza

NETHERLANDS Netherlands Organization for Scientific Research (NWO)
Council Member: Professor Dr. Stan Gielen

NORWAY The Research Council of Norway (RCN)
Council Member: Dr. Kirsten Broch Mathisen

PAKISTAN Pakistan Academy of Sciences
Council Member: Professor Dr. Kauser Abdulla Malik

RUSSIA Russian Academy of Sciences (RAS)
Council Member: Academician Professor Alexei Gvishiani

SOUTH AFRICA National Research Foundation (NRF)
Council Member: Dr. Dorsamy (Gansen) Pillay

SWEDEN The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (FORMAS)
Council Member: Dr. Ingrid Petersson

UKRAINE Ukrainian Academy of Sciences
Council Member: Academician Professor Dr. Anatoly G. Zagorodny

UNITED KINGDOM Research Councils of the UK
Council Member: Professor Duncan Wingham

UNITED STATES OF AMERICA The National Academy of Sciences (NAS)
Council Member: Professor Donald Saari

VIETNAM Vietnam Academy of Science and Technology (VAST) Council Member: Professor Dr. Ninh Khac Ban

The IIASA Council

As the governing body of the institute, the IIASA Council is composed of one permanent representative from each NMO. The Council meets twice a year, in June and November. The Charter and subsequent resolutions of Council document the role of Council, its processes, and decisions.

The Council is responsible for: establishing relations with government and international bodies; determining financial and managerial policies and subject areas for IIASA research; and ensuring IIASA activities are in line with its objectives, the provisions of the Charter, and the interests of the NMOs. The Council elects a chair and vice chairs who are the officers of the Council.

On 11 November 2014 Don Saari was appointed as the chair of the council, with Alexei Gvishiani and Prabhat Ranjan acting as vice chairs. Their term runs until 31 December 2018.

The Council appoints the director general and the deputy director general (the Directorate) who, as the chief executive officers of the institute, are responsible for implementing the research program and managing the day-to-day operations. In 2012, the Council appointed Professor Dr. Pavel Kabat as the 10th Director General of IIASA. Kabat, a Dutch citizen, came to IIASA from Wageningen University in the Netherlands. Professor Dr. Nebojsa Nakicenovic, an expert on how energy systems can be transformed for a sustainable future, is the deputy director general and was first appointed by Council to this role in 2008.
The IIASA Council exercises its oversight responsibilities through a committee structure: an Executive committee, a Finance Committee, a Membership Committee, a Program Committee, an Outreach and Capacity Building Committee, an external Science Advisory Committee, and external Evaluation Committees.

Evaluation and quality control

The IIASA Council oversees an array of activities designed to support its responsibility to offer guidance and assure the quality and relevance of IIASA research. It serves as a critical element of NMOs' assurance of the value of IIASA work in return for member countries' contributions.

Every ten and five years the Council provides input to and officially approves the institute's ten-year strategic plan and five-year research plan. In 2015, following a number of rounds of feedback and discussion between Council, the Directorate, and IIASA staff, Council approved the 2016-2020 Research Plan which was bought into effect on 1 January 2016.

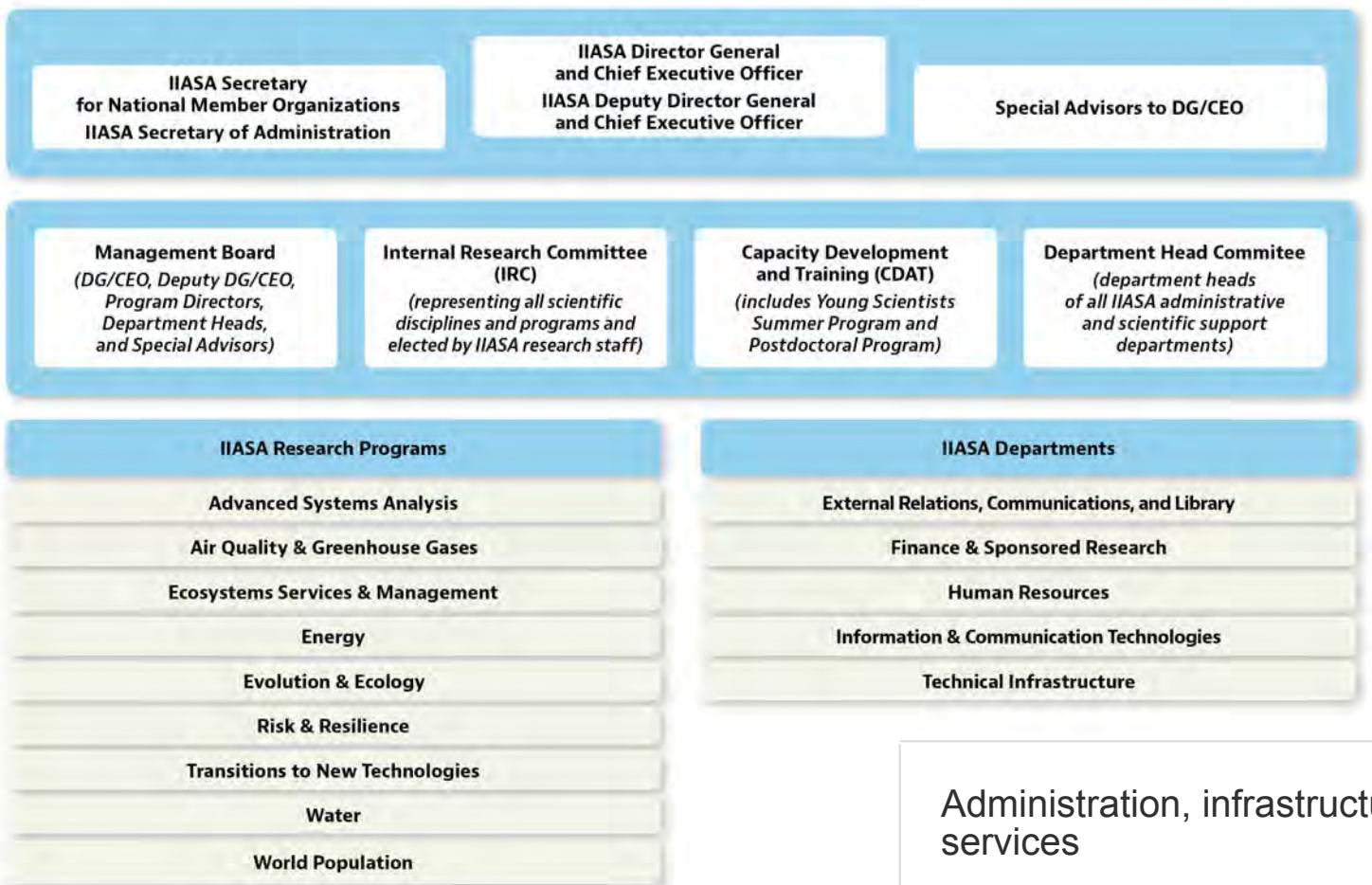
The Council also organizes periodic evaluations of IIASA research by a panel of independent, external experts to ensure IIASA research is of the highest quality and is aligned with the institute's research plan. In June 2012, the Council approved a new cycle of external evaluations which has reviewed the research quality, policy relevance, and effective use of systems analysis of all nine research programs. The results were overwhelmingly positive.

In 2016 the Council commissioned an institutional review by an independent panel of experts to provide an independent and comprehensive evaluation of IIASA including all structures, processes, and activities. The review aims to answer the overarching question of whether the general mission and ambitions, the organizational structure and governance, and the scientific programs and their policy-relevant implications are fit-for-purpose and future-proof. It will report its findings in 2017. The Council also reviews and approves the IIASA Annual Report, giving an overview of the year's achievements.

Another component of research oversight is the IIASA Science Advisory Committee (SAC). The SAC, established by the IIASA Council in 2002, comprises 15 international experts in fields relevant to IIASA research and its science-to-policy portfolio. SAC has an academically and geographically diverse membership—based partly on nominations from NMOs—and includes experts in the main areas of IIASA research. In 2016 its role continued to be to provide expert, independent, expert advice to the IIASA Council and Directorate to ensure that the institute's work continues to meet highest scientific and policy-relevance standards.

In addition, individual NMOs may undertake periodic reviews of IIASA research as part of their funding renewal processes. In 2016, the Dutch NMO, the Netherlands Organization for Scientific Research conducted an evaluation of its membership of IIASA and recommended to "continue Dutch membership at IIASA for 5 years."

Internal Governance



The internal decision-making authority is held by the Directorate as specified by the IIASA Charter (Article IX) and consistent with Austrian law.

Along with the internal advisory committees—the Management Board, Internal Research Committee, Department Heads Committee, and Capacity Building and Academic Training (see diagram)—a number of ad-hoc committees to advise the Directorate on important institutional matters have been established in the last four years. These include the Committee on Cultural Diversity and Building a Positive Work Environment, Open Access to Data Taskforce, Project Management Taskforce, Contact Database Task Force, and Information and Communication Technologies Forum. All these committees have a consultative and advisory role with decisions taken by the Directorate.

Administration, infrastructure, and services

IIASA research is supported by high-quality administration, infrastructure, and services. The current administrative departments include:

- External Relations, Communications, and Library
- Finance and Sponsored Research
- Human Resources
- Information and Communication Technologies
- Technical Infrastructure

In 2016, responsibility for NMO-relations was added to the Communications, Library, and Media department to form the new External Relations, Communications, and Library department.

Operating rules and procedures

In 2016, IIASA undertook a stocktake of all documented operating rules and procedures and is currently in the process of standardizing these to ensure consistency, transparency, accessibility, and best practice. This process, which will be completed in 2017, will also enable the institute to identify rules and procedures that need to be updated, better documented, or both.

Compliance and risk management

Compliance with constructive policy is important for IIASA, in the wider institute as well as for risk management. Although risks are always considered when management makes decisions at IIASA, the institute does not systematically assess mid- and long-term risk and does not systematically manage for it. Compliance to IIASA rules and policies is also not systematically monitored or assessed, and there is a lack of in-house expertise on how to implement compliance.

Although risks are always considered when management makes decisions at IIASA, the institute does not systematically assess mid- and long-term risk and does not systematically manage for it. Compliance to IIASA rules and policies is also not systematically monitored or assessed, and there is a lack of in-house expertise on how to implement compliance.

In 2016 Council asked IIASA to develop a risk register in order to manage risk over the long term and to conduct an external review of compliance and assurance processes. IIASA Directorate began preparations by seeking the advice of a governance and compliance expert from one of the NMOs, who visited IIASA in February 2017.

Health, safety, and wellbeing

IIASA complies with the Luxembourg Declaration on Workplace Health Promotion and the Austrian Employee Safety Law (ArbeitnehmerInnenschutzgesetz).

These laws stipulate that an occupational health doctor must be employed by the institute. Since 1997 IIASA has worked with a general practitioner qualified in occupational medicine, and in 2017 IIASA hired an occupational psychologist.

In addition to Austrian Safety Law, which covers work equipment, materials, and employee health, IIASA also adheres to:

- The Bildschirmverordnung which regulates **work with computers/screens**. Focusing on topics like the position (height and distance) of the computer screen, the adjustment (height and positioning) of the chair, the height of the desk, the lighting and the ergonomically appropriate set up of offices.
- Regulations regarding training for **first aid** officers and first aid equipment.
- Regulations regarding the appointment of a **safety specialist**.
- Regulations regarding the **protection of non-smokers**.

IIASA reports work-related accidents as legally required; in 2016 no notable incidents were reported.

The institute has guidelines regarding the following Health and Safety issues (detailed in the IIASA Handbook):

- Maternity regulations,
- On-Duty Accidents,
- Fire prevention,
- Smoking
- Prevention of health risks while working with computers.

These all fall under the legal framework in Austria regarding Health and Safety in the work place (i.e., ArbeitnehmerInnenschutzgesetz, Mutterschutzgesetz, Bildschirmverordnung).

In 2016, IIASA reviewed the number of first aid officers at work. In 2017 a number of new officers will be trained and existing officers will receive refresher training. All first aid kits at IIASA are updated quarterly.

In 2010 fire detectors were installed in every office in the Schloss, and in 2015 they were installed in Schloss Restaurant and surrounding buildings. Every three years external specialists provide fire training to IIASA fire wardens.

In 2016 the waste press was replaced with improved safety measures, and new safe, more stable ladders were purchased.

During 2016 IIASA had a dedicated external safety specialist who regularly visited IIASA to advise on health and safety regulations at the institute, with a specific focus on Arbeitsplatzsicherheit—workplace safety. As of 2017 IIASA started working with a new external safety services company. This company will provide a specialist to support the institute's doctor and psychologist to evaluate and document the implementation of the laws and guidelines listed above and come up with strategies to improve employee health at work

Financials

The work of IIASA is made possible through the generous support of a range of organizations and individuals that share the institute's commitment to independent, interdisciplinary research into pressing global problems.

Annual budget in 2016 was €22 million, of which 56% was from prestigious research funding agencies in 24 countries in Africa, the Americas, Asia, Europe, and Oceania. These diverse sources of income enable IIASA to perform research that is truly independent.

Additional funding comes from contracts, grants, and donations from governments, international organizations, academia, businesses, and individuals. Between 2012 and 2016 this additional funding reached €45 million. This is part of a funding portfolio of €360 million — the total awarded to external partner and consortia projects featuring collaborations with IIASA.

Contracts and grants 2016

Policies and procedures

Research Funding Agencies

In 2016 IIASA membership contributions were provided by the following agencies:

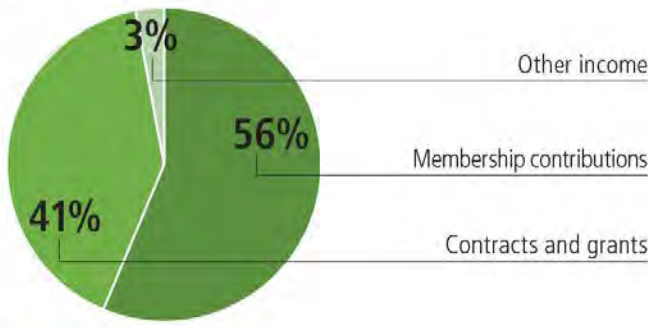
The Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia • The Austrian Academy of Sciences (OEAW) • The Brazilian Federal Agency for Support and Evaluation of Graduate Education (CAPES) • National Natural Science Foundation of China (NSFC) • Ministry of Finance, Egypt • Academy of Finland • Federal Ministry of Education and Research (BMBF), Germany • Technology Information, Forecasting and Assessment Council (TIFAC), India • Ministry of Foreign Affairs, Indonesia • Ministry of the Environment, Japan • National Research Foundation of Korea (NRF) • Ministry of Science, Technology and Innovation, Malaysia • National Council for Science and Technology (CONACYT) and National Institute of Statistics and Geography (INEGI), Mexico • Netherlands Organization for Scientific Research (NWO) • The Research Council of Norway (RCN) • Planning Commission, Pakistan • Russian Academy of Sciences (RAS) • National Research Foundation (NRF), South Africa • The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (FORMAS) • Ukrainian Academy of Sciences • Economic and Social Research Council (ESRC), Engineering and Physical Sciences Research Council (EPSRC), and Natural Environment Research Council (NERC), UK • National Science Foundation (NSF), USA • Vietnam Academy of Science and Technology (VAST)

Summary of the Statement of Activities (draft)

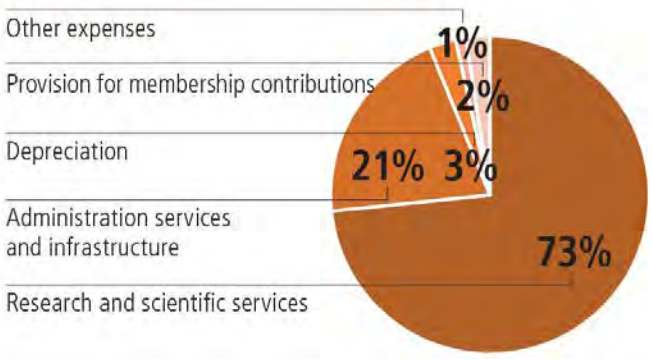
INCOME	31-DEC-16 (€)	31-DEC-15 (€)
Membership contributions	12,405,500	11,793,000
Contracts and grants	8,976,741	9,825,924
Other income	643,739	461,138
TOTAL INCOME	22,025,980	22,080,062
EXPENDITURES		
Research and scientific services	15,966,713	15,834,959
Administrative services and infrastructure	4,447,599	4,367,944
Depreciation	590,135	568,633
Other expenses	230,196	185,574
Provision for membership contributions	523,500	842,500
TOTAL EXPENDITURE	21,758,143	21,799,610
CHANGE IN NET ASSETS	267,837	280,452

As at 31 December 2016

Income



Expenditures



Summary of the Statement of Financial Position (draft)

	31-DEC-16 (€)	31-DEC-15 (€)
NON-CURRENT ASSETS		
Property, plant, and equipment	1,045,089	1,220,121
TOTAL NON-CURRENT ASSETS	1,045,089	1,220,121
CURRENT ASSETS		
Inventories	25,820	22,354
Work in progress	1,717,401	2,141,911
Receivables and prepayments	4,753,065	6,883,146
Cash and cash equivalents	11,863,364	9,460,427
TOTAL CURRENT ASSETS	18,359,650	18,507,838
TOTAL ASSETS	**19,404,739**	**19,727,959**
ASSETS HELD IN TRUST	*11,882,998*	*11,408,580*

NET ASSETS		
Restricted funds	1,052,766	1,227,798
Unrestricted funds	7,273,019	6,830,150
TOTAL NET ASSETS	8,325,785	8,057,948
NON-CURRENT LIABILITIES		
Provisions	2,470,220	2,434,269
TOTAL NON-CURRENT LIABILITIES	2,470,220	2,434,269
Prepayments	5,519,726	4,424,695
Provisions	1,421,103	2,904,144
Other liabilities	1,667,905	1,906,903
TOTAL CURRENT LIABILITIES	8,608,734	9,235,742
TOTAL LIABILITIES	11,078,954	11,670,011
TOTAL LIABILITIES & NET ASSETS	**19,404,739**	**19,727,959**
TRUST LIABILITIES	*11,882,998*	*11,408,580*

As at 31 December 2016

Full financial statements, including all schedules and accompanying notes, are available on request.

Donations

IIASA gratefully accepts donations that help increase the impact of the institute's research and bridge economic gaps by funding fellowships for scholars from underprivileged regions. There are various ways to support the IIASA mission.

The Annual Fund provides funds for a three-month Young Scientist Summer Program (YSSP) scholarship given to a promising young researcher from a developing country. Generous donations from IIASA supporters enabled five exceptional young scientists to participate in the 2016 YSSP.

The Peter E. de Jánosi Postdoctoral Fellowship fund—set up in honor of former IIASA director, Dr. de Jánosi—offers selected postgraduate students the opportunity to participate in the IIASA Postdoctoral Program.

An unrestricted donation to the IIASA Fund provides opportunities for endeavors outside the institute's budget and allows IIASA the freedom to continue conducting independent and interdisciplinary research to find solutions to a host of scientific, social, and policy problems.

The institute continues to receive generous support through the non-governmental organization Friends of IIASA, which enables US residents to make tax deductible donations to the institute.

IIASA thanks all donors for their generosity in 2016 and is grateful for their commitment and belief in the mission of the institute.

Contracts and Grants 2016

Funder:

- Commonwealth Scientific and Industrial Research Organisation (CSIRO), Queensland, Australia
- Austrian Academy of Sciences, Vienna, Austria
- Austrian Climate Research Program (ACRP), Vienna, Austria
- Austrian Development Agency (ADA), Vienna, Austria
- Austrian Environment Agency, European Topic Center on Urban, Land and Soil Systems Environment Agency Austria (EAA), Vienna, Austria
- Austrian Research Promotion Agency (FFG), Vienna, Austria
- Austrian Science Fund (FWF), Vienna, Austria
- Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW), Vienna, Austria
- Kommunalkredit Public Consulting GmBH, Vienna, Austria
- The Central Institution for Meteorology and Geodynamics (ZAMG), Vienna, Austria
- United Nations Industrial Development Organization (UNIDO), Vienna, Austria
- YSSP Annual Fund, Laxenburg, Austria
- Association for Emissions Control by Catalyst (AECC), Brussels, Belgium
- European Commission, Communications Networks, Content and Technology, Brussels, Belgium
- European Commission, DG Clima, Brussels, Belgium
- European Commission, DG Climate Action, Brussels, Belgium
- European Commission, DG Climate Change and Air, Brussels, Belgium
- European Commission, DG Energy, Brussels, Belgium
- European Commission, DG Environment, Brussels, Belgium
- European Commission, DG Research and Innovation, Brussels, Belgium
- European Commission, Directorate-General for Development and Cooperation, EuropeAid, Brussels, Belgium
- European Commission, European Research Area, ERA-NET Cofund, Brussels, Belgium
- European Commission, European Research Council Executive Agency (ERC), Brussels, Belgium
- European Commission, Executive Agency for Small and Medium-sized Enterprises (EASME), Brussels, Belgium
- European Commission, Innovation and Networks Executive Agency (INEA), Brussels, Belgium
- European Commission, Research Executive Agency (REA), Brussels, Belgium
- European Commission, Sustainable food (SFS), Brussels, Belgium
- European Commission Innovation and Networks Executive Agency, Brussels, Belgium
- Center for Strategic Studies and Management (CGEE), Brasilia, Brazil
- Nationanal Institute of Science and Technology (INCT), Sao Paulo, Brazil
- International Center for Tropical Agriculture (CIAT), Cali, Columbia
- Strategic Research Council, Academy of Finland, Helsinki, Finland
- French National Institute for Industrial Environment and Risks (INERIS), Verneuil-en-Halatte, France
- International Energy Agency (IEA), Paris, France
- United Nations Educational, Scientific and Cultural Organization (UNESCO), Paris, France
- Federal Ministry for Economic Cooperation and Development (BMZ), Berlin, Germany
- Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), Bonn, Germany
- International Climate Initiative, German
- Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Berlin, Germany
- The Alfred-Wegener-Institute for Polar and Marine Research, Bremerhaven, Germany
- The Umwelt Bundesamt (UBA), Berlin, Germany
- Institute of Communication and Computer Systems, National Technical University of Athens, Greece
- Center for International Forestry Research (CIFOR), Bogor, Indonesia
- Food and Agriculture Organization of the United Nations(FAO), Rome, Italy
- International Fund for Agricultural Development (IFAD), Rome, Italy
- Italian Agency for New Technology Energy and the Environment (ENEA), Rome, Italy
- The Joint Research Centre (JRC), Ispra, Italy
- Institute for Global Environmental Strategies (IGES), Kanagawa, Japan
- National Institute for Environmental Studies (NIES), Ibaraki, Japan
- Research Institute of Innovative Technology for the Earth (RITE), Kyoto, Japan
- Toyota Central Research & Development Laboratories, Inc. (TCRDL), Aichi, Japan

Contracts and Grants

- Toyota Motor Corporation, Aichi, Japan
- Eurasian Development Bank, Almaty, Kazakhstan
- The International Livestock Research Institute (ILRI), Nairobi, Kenya
- Changsin University, Changwon, Korea, Republic of Korea
- Science and Engineering Foundation (KOSEF), Daejeon-City, Republic of Korea
- Ferrero Trading Lux, Findel, Luxembourg
- International Maize and Wheat Improvement Center (CIMMYT), Mexico City, Mexico
- European Space Agency (ESA) - ESTEC, Noordwijk, Netherlands
- LEI - Part of Wageningen University, Netherlands
- NordForsk funded project, GreenMar, Oslo, Norway
- Norwegian Agency for Development Cooperation (NORAD), Oslo, Norway
- Norwegian Meteorological Institute (met.no), Oslo, Norway
- Norwegian Ministry of Climate and Environment, Oslo, Norway
- Alfa Bank, Moscow, Russia
- World Wide Fund SA, Cape Town, South Africa
- Swedish Environmental Research Insitute Ltd (IVL), Stockholm, Sweden
- Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (FORMAS), Stockholm, Sweden
- Swedish University of Agricultural Sciences (SLU), Umeå, Sweden
- United Nations Economic Commission for Europe (UNECE), Geneva, Switzerland
- Zurich Insurance Company Ltd., Switzerland
- United Nations Environmental Programme (UNEP) - Regional Office for Asia Pacific, Bangkok, Thailand
- University of Nottingham, United Kingdom
- Climateworks Foundation, San Francisco, USA
- Environmental Defense Fund (EDF), New York, USA
- Formerly Research Triangle Institute (RTI) International, Research Triangle Park, North Carolina, USA
- Global Environmental Facility, Washington D.C., USA
- National Science Foundation (NSF), Virginia, USA
- Pew Research Center, Washington D.C., USA
- RAND Corporation, Santa Monica, USA
- Rockefeller Philanthropy Advisors, New York, USA
- The World Bank, Washington D.C., USA
- University of Maryland, USA

Financial policies and procedures

The Finance Committee of Council supervises accounting and audit, annual payments of NMO contributions, realization of royalties and other revenues, and annual financial reports. IIASA is also legally obliged under the Austrian Association Act and Austrian commercial law to have its accounts externally audited every year (latest audited accounts for 2016 **link pending**). Until 2015, auditing of the annual accounts was carried out by PriceWaterhouseCoopers, this has now changed to BDO Austria who will audit IIASA's statutory financial statements for 2016.

In addition, some external funders mandate that the projects they contribute to be individually audited. The European Commission (EC), a major contributor to the institute's external funding, also sometimes performs second-level audits on already externally audited EC projects. To date three major second-level audits have been carried out on nine projects in 2009, 2011, and 2015. The next second-level audit will take place in early April 2017.

At IIASA financial policies and procedures are in place for:

- sponsored research and budgeting for a proposal (sections 4.4.7 and 4.4.8 of the IIASA Operating Procedures and Policies).
- procurement, business travel, holding conferences, and visits from external collaborators and stakeholders (section 4.4 of the IIASA Operating Procedures and Policies).
- budget planning and oversight process as shown in the diagram below (section 4.4.2 in IIASA Operating Procedures and Policies).

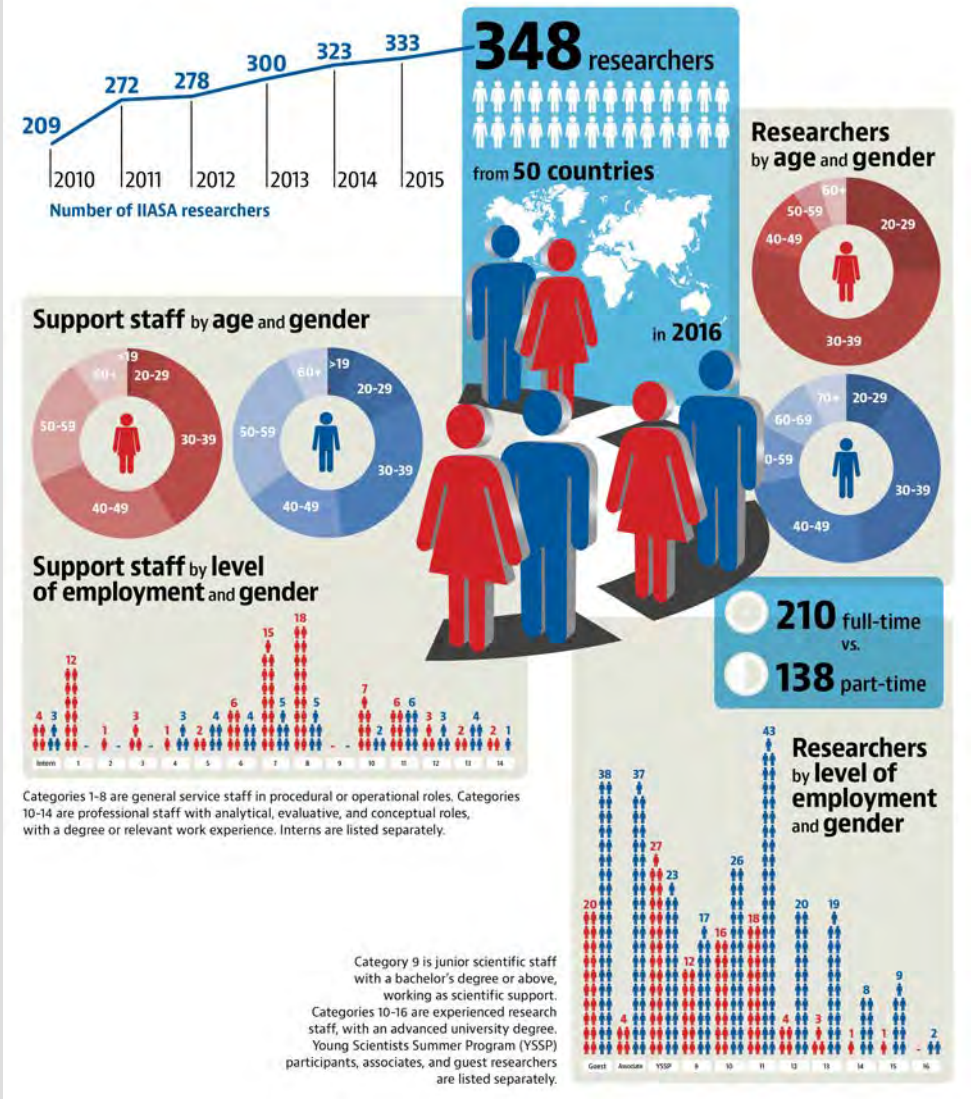
The procedures and approval processes are facilitated and documented through the IIASA management information system.

Financial summaries

Our people

The people at IIASA are its most valuable asset and the institute continues to attract and retain world-class talent. Researchers from IIASA member countries' working at the institute gain access to new perspectives, methodologies, and funding, and can help build the systems analysis capacity of their home countries. Currently, over 300 international researchers from around 50 countries work for IIASA and another 2,500 researchers, science-to-policy workers, and diplomats from about 65 countries are actively involved in IIASA activities.

IIASA network



People management

Human capital management is of the highest priority at IIASA for the next five years following a period of rapid expansion of the numbers of researchers and staff working at the institute. To that end, a new Head of Human Resources, who also acts as the IIASA Secretary for Administration, was appointed in October 2016, and a new staff performance evaluation system and diversity policy are under development.

In addition to Austrian labor law, a series of federal laws concerning IIASA and international organizations in Austria provide the institute and its employees with a range of immunities and privileges allowing IIASA to offer competitively advantageous employment conditions compared to Austrian employers (Austrian federal law and official gazettes: BGBl. Nr. 117/1973; BGBl. Nr. 677/1977; BGBl. Nr. 344/1978; BGBl. Nr. 476/1978; BGBl. Nr. 441/1979; BGBl. Nr. 219/1981; BGBl. Nr. 609/1990; BGBl. Nr. 666/1994).

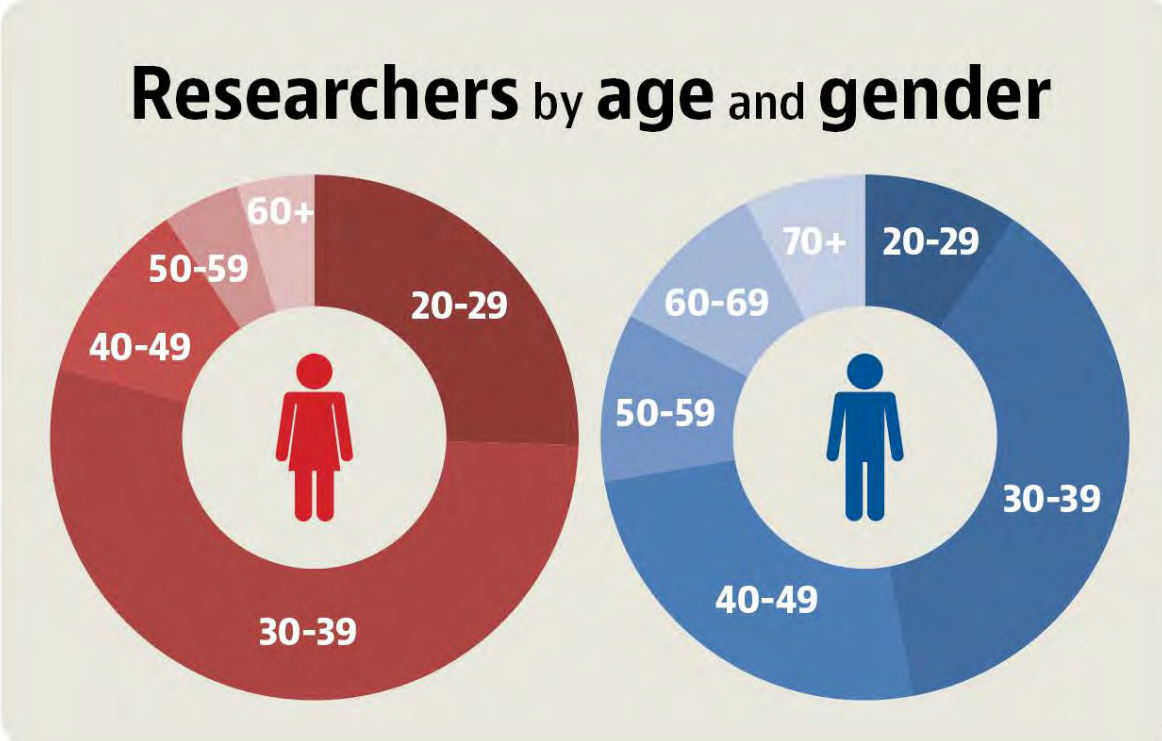
Human resource policies and procedures are in place for staff categories, personnel procedures, overtime, leave, maternity regulations, childcare benefits, retirement, temporary assignment, incentive payments, good scientific practice, conflicts of interest and commitment, code of conduct, outside interests, housing services, and health and safety rules. These policies are in the IIASA handbook and staff rules and regulations (sections 4.2 and 4.3 of the IIASA Operating Procedures and Policies). Hiring and extending staff is implemented and documented through the forms and approval processes of the IIASA management information system.

IIASA guidelines and regulations for good scientific practice

IIASA guidelines and regulations for good scientific practice were updated in 2016. They are intended to contribute to avoiding scientific misconduct, conflicts of interest and commitment as well as promoting quality science. The institute recognizes its responsibility to nurture an environment of mutual respect, tolerance, and ethical behavior according to the general principles outlined in these rules. No such cases of scientific misconduct arose in 2016.

Diversity and equality

One of the many characteristics that make IIASA unique is its innovation and legitimacy that stems from its diversity. IIASA has demonstrated the scientific value of bringing together different nationalities and disciplines to work toward common goals, and continues to value diversity and equality. IIASA also recognizes that diversity, while a great benefit overall, brings challenges in terms of managing cultural, social, and geographic diversity.



The Committee on Cultural Diversity and Building a Positive Work Environment, made up of staff volunteers appointed by the director general, collected and analyzed employment data at IIASA, conducted a staff survey and prepared the 2015 Report on Diversity and the Work Environment. This set out a series of recommendations for increasing diversity and equality at IIASA.

As part of this report, a gender pay gap was identified. The Human Resources department investigated this gap by looking in detail at each employee's salary to see whether there was pay gap that could be directly related to gender. Disparities in the salaries of around 27 employees were found and in more than half of the cases identified, remedial action has already been taken. The rest will be dealt with in 2017.

IIASA also recruited a new institute counselor in 2016 as a work psychologist to provide counseling related to cultural and social diversity and work environment issues.

The Charter stipulates that at least two thirds of the research scholars should be from NMO countries, and each NMO country has the right to have at least one research scholar at IIASA. With this in mind, IIASA informs the NMOs of researcher vacancies and reports to Council on the numbers and nationality of all its staff.

However, IIASA acknowledges that more can be done and in 2017 a dedicated Diversity Task Force, with the support of an external professional, will produce a Diversity Policy for IIASA. It will aim to increase diversity throughout the workforce, and foster a workplace accommodating diversity of all sorts, spanning culture, gender, race, disability, and religion. The initial terms of reference will include an assessment of diversity, an analysis and benchmark of diversity compared with other organizations, and the development of a vision for a more diverse workforce at IIASA.

IIASA Code of Conduct

All IIASA staff must be treated equally and with respect, regardless of gender, race, religion or belief, nationality, ethnic or social origin, age, sexual orientation, marital status, or other aspects of personal status and no behavior can be tolerated at IIASA that constitutes harassment, sexual harassment, discrimination, bullying, retaliation, or any related acts.

The IIASA Code of Conduct Policy for a Professional Working Environment was updated in 2016. This policy specifically extends personnel procedures to include unprofessional behaviors in the workplace, namely: harassment, sexual harassment, discrimination, bullying, and retaliation.

Responsibilities of IIASA, the staff, and the management are clearly outlined in the Code of Conduct. IIASA staff found to have breached these conditions are subject to disciplinary action in accordance with Article IX, *Disciplinary Measures* of the IIASA Staff Rules and Regulations. This may include an oral or written reprimand, or summary dismissal in accordance with the applicable Austrian laws. The failure by management to address a violation of the Code of Conduct that has come to their knowledge may result in appropriate legal or disciplinary measures being taken against them.

In 2016 two incidents were brought to the IIASA Human Resource Department and were professionally handled and solved in accordance with the IIASA Code of Conduct.

Learning and development

In addition to scientific education and training, in member countries and though the Young Scientists Summer Program and Postdoc Program, IIASA also supports general and professional staff to develop their skills and expertise to increase their employability and to develop their full potential. Training and development opportunities are agreed upon on a case by case basis between the supervisors and employees.

In 2016 a need to review the current performance evaluation, job level, and job title systems at IIASA was identified, in order to attract top candidates and retain world class talent. Therefore, job levels, job titles, and job criteria will be reworked, job descriptions and classifications will be updated, and existing salary scales will be evaluated and if necessary adapted to be market-compliant. Furthermore, a new system of regular performance reviews, with staff development as a key factor, will be set up. Priority will be given to this important and extensive project in 2017/2018.

In 2016, 348 researchers from 50 countries worked at IIASA, 2,229 collaborators visited IIASA, and around 25% of IIASA alumni were actively involved in the institute. Together, they made up a global research network of over 3,500 scholars.

3,910
alumni from 86 countries, among them leaders in academia, government, and the private sector

154
advisory boards and steering committees incorporating IIASA researchers

150
externally funded projects where IIASA was the lead or partner

406
journal articles in collaboration with over 1,500 coauthors from 159 institutions in 50 countries

IIASA network

Visitors In 2016, a total of 2,299 associates and scholars visited IIASA for research and collaboration and to attend at IIASA-organized events. Of those visitors, 1,933 were from member countries.

Research network IIASA has a worldwide network of 3,500 scholars from around the world, who assist in research through collection, processing, and evaluation of local and regional data that are then integrated into IIASA models. IIASA has over 720 research partner institutions in national member countries and works with research funders, academic institutions, policymakers and individual researchers in national member organizations.

Alpbach–Laxenburg Group Founded by IIASA and the European Forum Alpbach, the group continued its strategic partnership in 2016, bringing together some of the world's best minds from government, academia, business, civil society, and the arts. These science–based, policy–centered deliberations focused on the role of the private sector in achieving the sustainable development goals.

Alumni Association IIASA has 3,910 alumni from 86 countries, 25% of whom are actively involved in the institute's scientific activities. The Alumni Association aims to connect former staff with IIASA colleagues, providing numerous channel to support the institute and its work.

Meetings and events In 2016 IIASA scientists hosted or coordinated 92 events worldwide—of which 64 were convened in Laxenburg. The events were attended by a total of 1,867 conference participants, with 1,575 from member countries.

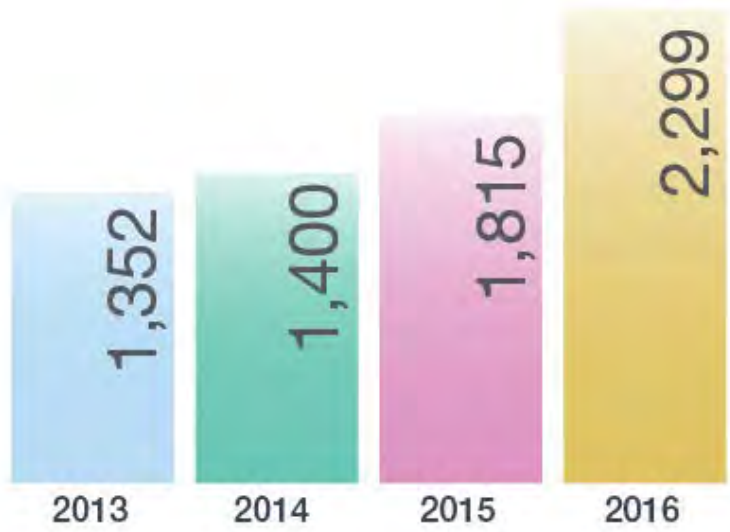
Our people

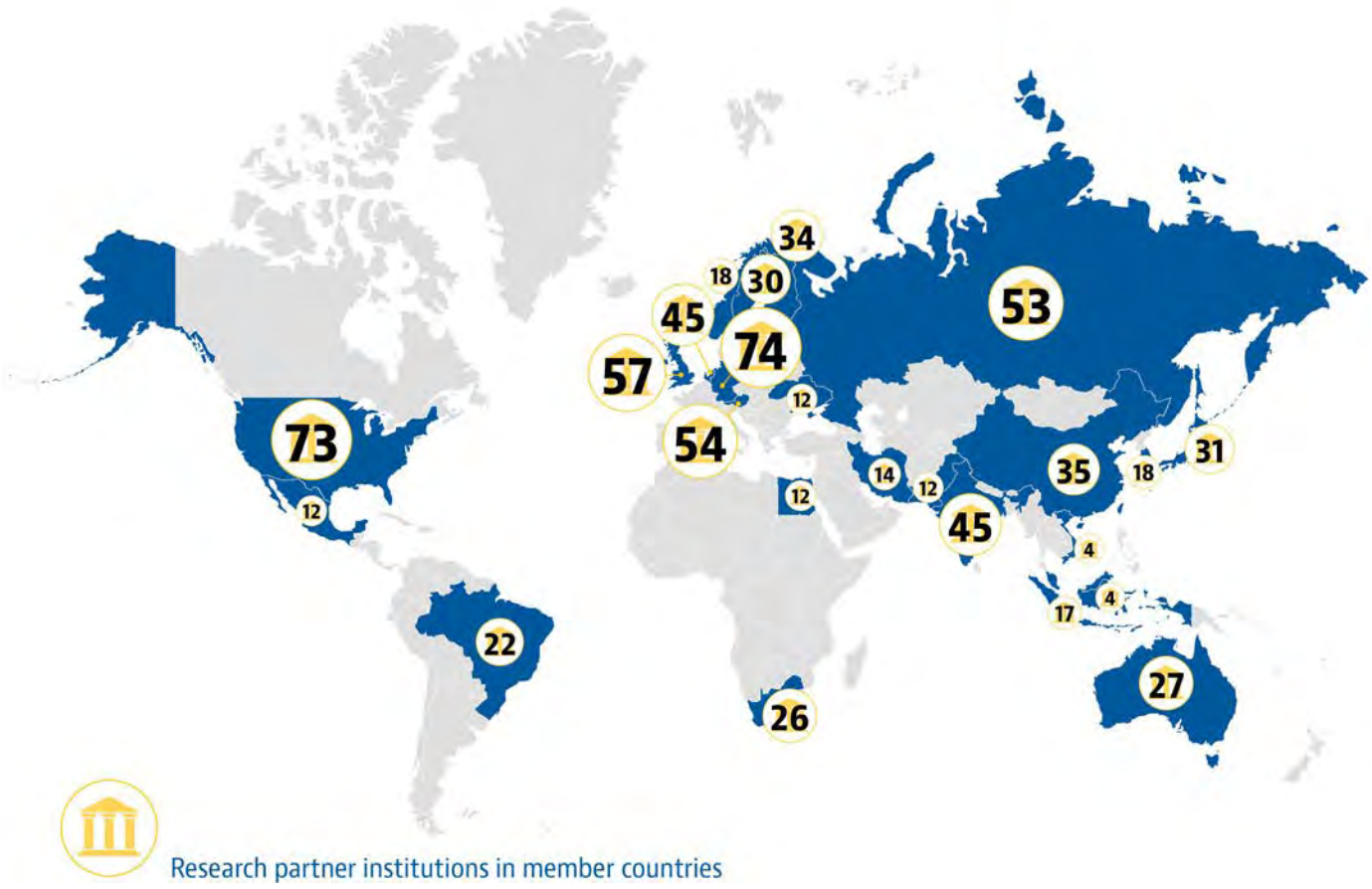
Distinguished Visiting Fellows

The institute welcomes visits by eminent scholars from around the globe, and three became Distinguished Visiting Fellows in 2016:

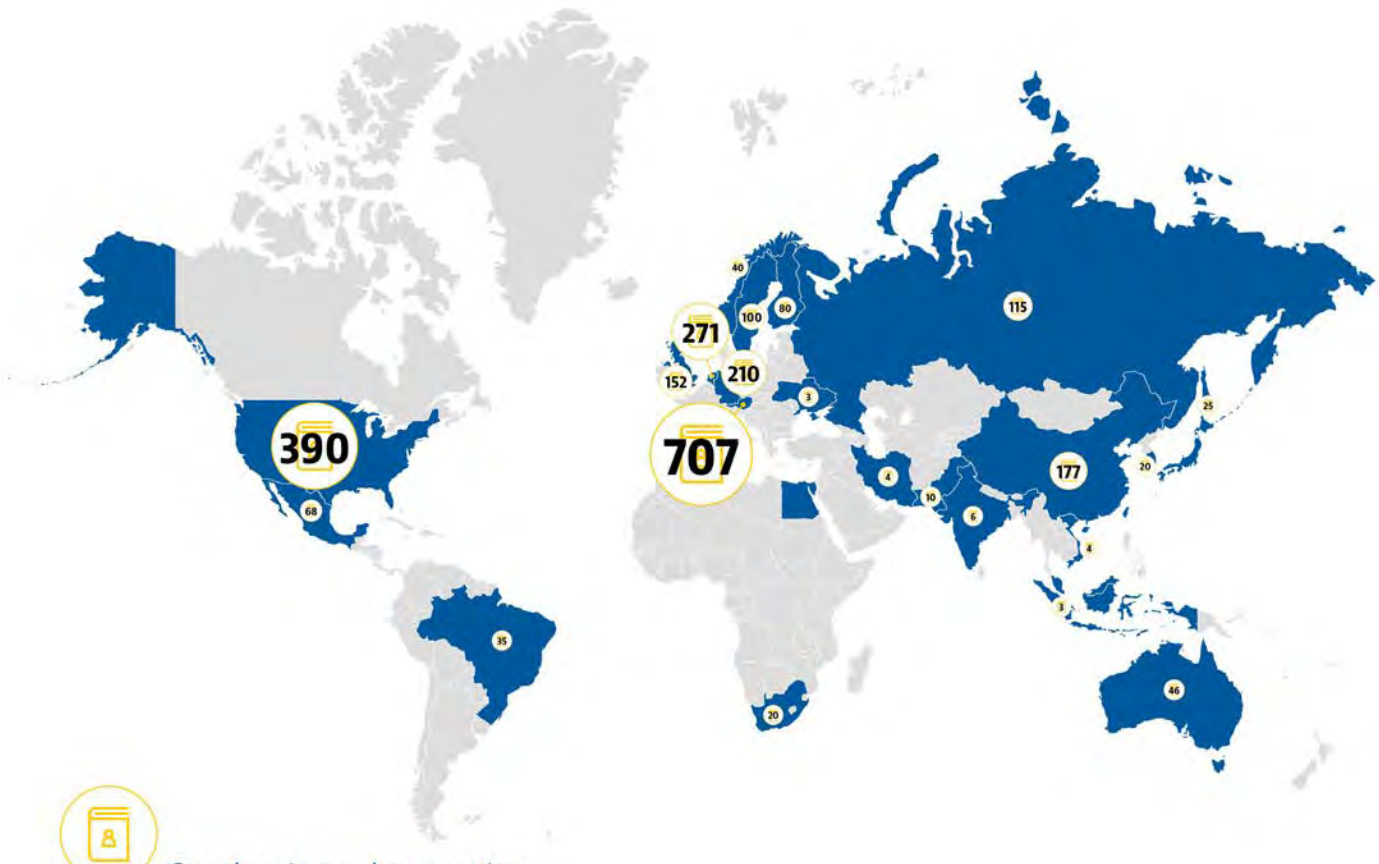
- Vladimir E. Fortov
- Hans Joachim Schellnhuber
- Shalini Randeria

IIASA visitors and conference participants



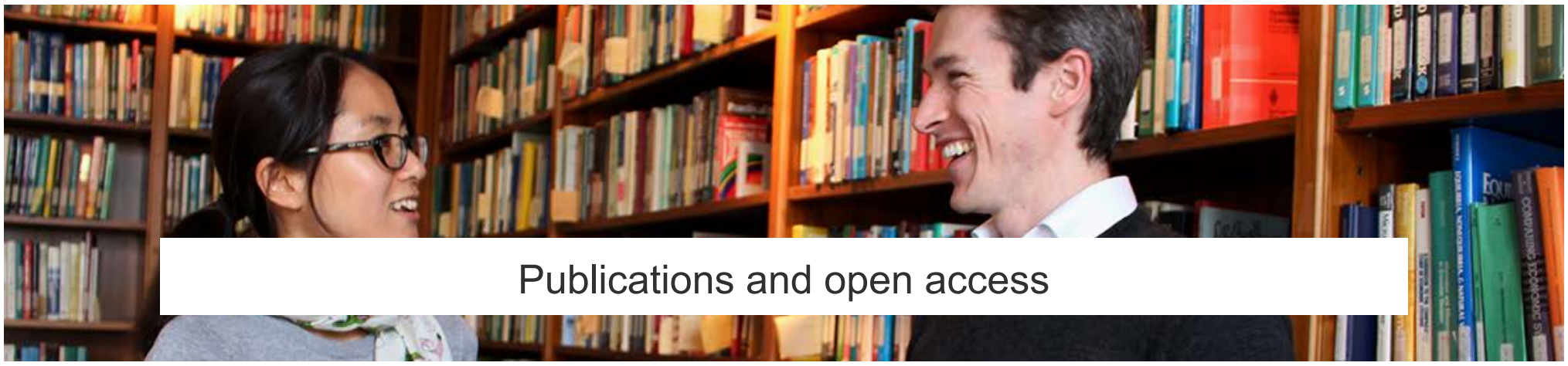


Research partner institutions in member countries



Coauthors in member countries

Alumni in member countries



Publications and open access

There were 615 IIASA publications in 2016, of which 406 were peer-reviewed journal articles, written in collaboration with over 1,500 coauthors from 159 institutions in 50 countries. The institute also launched its open access policy, which aims to make the full text of all peer-reviewed articles available, and achieved a 71% compliance rate in the first year.

IIASA follows the principles and rules laid out in its Scientific Publications Policy, which encourages the widest possible dissemination of researchers' work. The policy also sets out the principles governing the various types of publications used by the institute to communicate its research results to outside audiences.

2016 publications

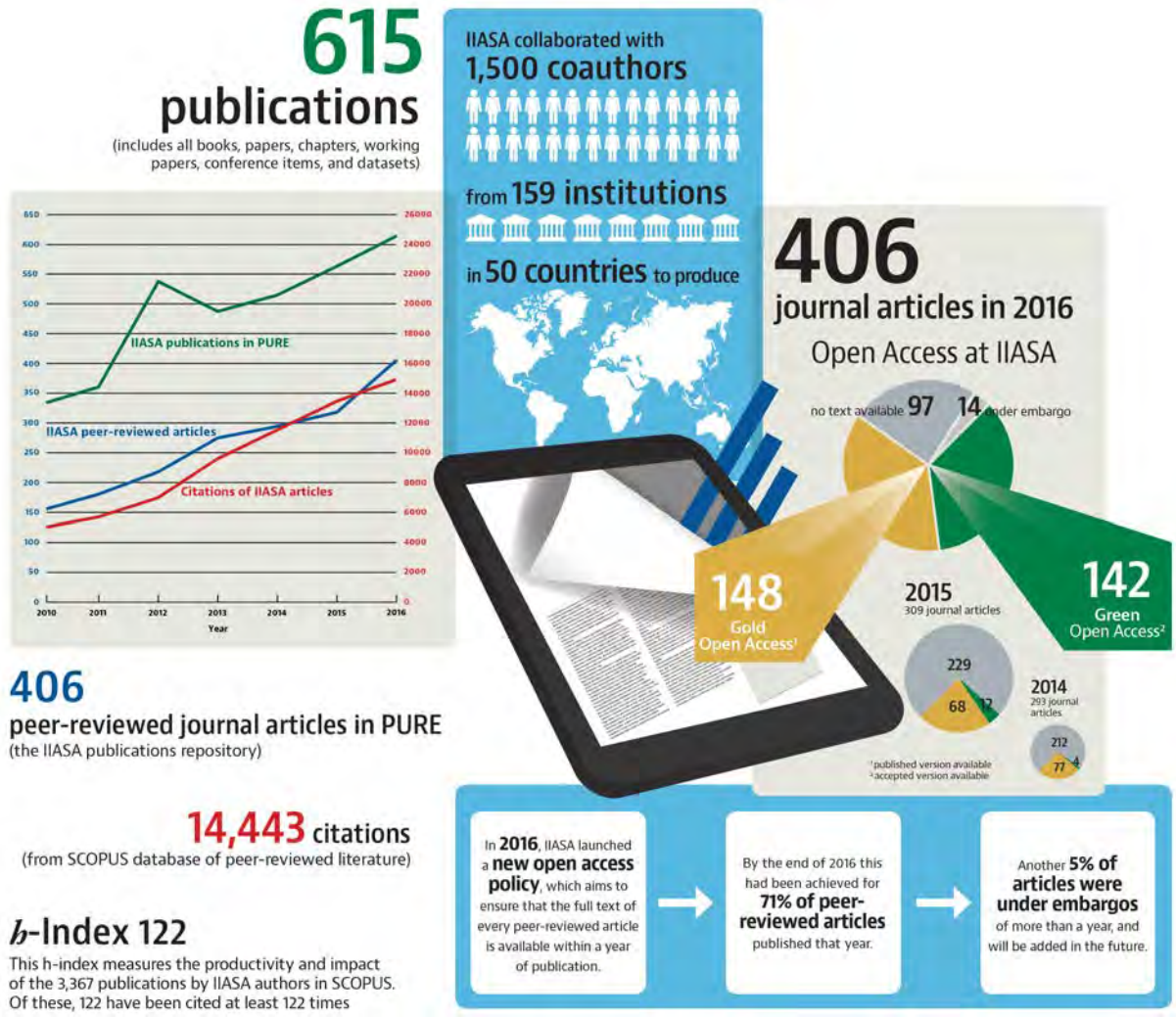
Open access – publications

In 2016, IIASA introduced a full open access policy for its publications in order to make its external and internal publications freely available via its new publications repository (PURE). The policy requires that all IIASA authors deposit a complete version of their peer-reviewed research articles in the IIASA institutional repository in order to make it freely accessible within a year of its online publication date (known as green open access).

IIASA encourages its researchers to publish their research in journal articles or books that are available for free to all users (gold open access) when possible. To support this IIASA has a fund for covering open access fees as of 2016 and is negotiating special agreements with publishers to offer more advantageous publishing options for its researchers.

To aid this endeavor a repository and open access manager was hired in 2016 to assist and encourage researchers to deposit materials, and to assure quality control and consistency of records and metadata.

PURE was launched in March 2016 and during the year a total 600 new publications were added. Out of these, 399 are articles, and 292 have an attached version, a compliance rate to the Open Access policy of 73%. For comparison, in 2009 the open access compliance level for Wellcome Trust-funded research was only 43% four years after introducing an open access mandate, and it was still only 55% in 2012. It was not until 2015 that compliance levels increased to over 70% after implementing sanctions for non-compliance.



Open access – data

Open access to data provides a range of advantages, such as improving the verifiability and reproducibility of the scientific results and making access to scholarly knowledge as barrier-free as possible. With this in mind, IIASA has established a task force which will take stock of the current status of open access data and research tools (e.g., models) at IIASA and explore alternative options for making data openly accessible, including an evaluation of the costs and benefits of alternative options at the level of individual scientists, research programs, and the institute as a whole.

The task force—made up of researchers and IT experts —will also propose a Research Data Management Policy that establishes general principles for IIASA datasets and tools and create a long term vision for making tools developed at IIASA openly available. They will present their vision at the June 2017 Council meeting.

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