Annual Report 2018

International Institute for Applied Systems Analysis
IIASA www.iiasa.ac.at

The International Institute for Applied Systems Analysis (IIASA) is an independent, international research institute with National Member Organizations in Africa, the Americas, Asia, and Europe. Through its research programs and initiatives, the institute conducts policy-oriented research into issues that are too large or complex to be solved by a single country or academic discipline. This includes pressing concerns that affect the future of all of humanity, such as climate change, energy security, population aging, and sustainable development. The results of IIASA research and the expertise of its researchers are made available to policymakers in countries around the world to help them produce effective, science-based policies that will enable them to face these challenges.

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IIASA
Annual report
2018

Message from the Council Chair and Director General

In 2018, IIASA researchers continued to produce world-class research and independent, science based insights that contribute to the achievement of global societal objectives like those embedded in the UN Sustainable Development Goals (SDGs) – especially for the world's poor and marginalized.

One of the institute's strengths is that it is truly multidisciplinary. Using both established and newly developed IIASA models and tools, crowd sourcing, and innovative games, researchers explored the challenges of issues like reducing disaster risk, building resilience, and ultimately contributing to sustainable development. This year's report also highlights how IIASA scientists are delving deeper into topics like climate smart agricultural policies, better air quality management practices, and technological innovations for achieving the SDGs, while engaging with science and policy communities in countries across Africa, Asia, the Americas, and Europe.

The institute's work is made possible through the support of the countries, organizations, and individuals that share our belief that finding comprehensive, practical solutions to the challenges the world faces. We would like to thank our member organizations and all our donors, for their continued support and generosity in 2018. We are truly grateful for their commitment to the IIASA mission. With their continued support, we will continue to build on the values that led to the establishment of IIASA more than 40 years ago, and further our mission to contribute to informed policymaking and building bridges across political divides in the coming years.

We would also like to thank all the IIASA staff for their contributions in 2018, the previous Director General Pavel Kabat, for successfully steering the IIASA ship through much of 2018 and the Acting Deputy Director General, Nebojsa Nakicenovic for Acting as Director and CEO during the transition in September 2018. Your collective efforts ensured that we could approach 2019 with confidence.

Michael Clegg
Council Chair

Albert van Jaarsveld
Director General and CEO

Pavel Kabat
Director General and CEO
February 2012- August 2018

Nebojsa Nakicenovic
Acting Director General
September 2018

THE IIASA MISSION is to provide scientific insight and guidance to policymakers worldwide by finding solutions to global problems through applied systems analysis. In this way, the work helps to improve human wellbeing and protect the environment.

IIASA Strategic Plan 2010-2020

IIASA Research Plan 2016-2020

Contents

Global

Many of the challenges society face today are too large or complex to be addressed by a single country or discipline. In 2018, IIASA research looked into numerous issues of global significance spanning topics ranging from food and water security, digitalization, and financial risk, to technological innovations for achieving the UN Sustainable Development Goals.

Selected highlights:

Exploring the impact of digitalization

Pioneering a new approach to systems transformations

Thinking small to ensure global food security

Supporting the policy discourse around Loss and Damage

Advanced Systems Analysis

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Exploring the impact of digitalization

With the advent of the internet and the expansion of the digital economy, an increasing portion of consumption cannot be evaluated in monetary terms and attributed in the traditional way. IIASA research explored the impact of digitalization on economies.

Governments are tasked with devising economic policies to improve the population's wellbeing, which is traditionally indicated by per capita consumption. Many services provided through the internet, however, are paid for by companies advertising their products – consumers do not pay for it themselves. As a result, this consumption is not reflected in national economic statistics including the country's gross domestic product (GDP). Services provided through the internet that are not priced and monetized in the traditional way, and therefore not part of the national GDP, are referred to as un-captured GDP.

IIASA research highlighted the phenomenon of un-captured GDP and demonstrated the limitations of current national statistics to properly account for those. The problem of un-captured GDP emerges because market prices do not necessarily reflect longitudinal changes in the quality of products. The study [1] reviewed several approaches that could be used to correct market prices, and hence the national statistics, to account for un-captured GDP. The paper highlights the significant shift in consumer preferences from purely economic functionality to supra-functionality beyond economic value. Further research [2] focused on Finland and Singapore – both world leaders in Information and Communications Technology (ICT) – and contrasted un-captured GDP trends between the two countries to explain the difference in their economic growth rates and welfare. An empirical analysis revealed that innovation of especially products and services of an aesthetic or intellectual nature have created un-captured GDP in Finland.

IIASA researchers also looked at the apparent productivity paradox in the digital economy, where for the last 15 to 20 years the ICT sector has become more interactive, integrated, and seamless. This interconnectedness is expected to create many new opportunities. However, while technological progress historically implied economic growth, in the internet era it seems that this is not the case. A possible explanation might be the two-faced nature of ICT: while capital accumulation in the ICT sector increases the price of products, the abundance of the internet actually decreases it, resulting in an overall decline of the price over time. Another IIASA study [3] empirically examined and confirmed this hypothesis.

Global ICT firms are embracing digital solutions and restructuring their business models toward more competitive digital business strategies. IIASA researchers [4] analyzed digital business solutions in 500 global ICT firms from 2005 to 2016 and discovered that research- and development-intensive firms have fallen into a trap in ICT advancement, resulting in a decline in their marginal productivity. This could be due to increasing dependency on un-captured GDP. As a result, these firms want to harness soft innovation resources and activate a self-propagating function that induces functionality development through sophisticated digital business strategies in response to un-captured GDP. This work highlights the significance of new, open, platform-based innovations in the digital economy.

More information ar18.iiasa.ac.at/digitalization

Ecosystems and Services Management

Thinking small to ensure global food security

A global data set of agricultural field sizes collected as part of a crowdsourcing project by IIASA researchers, has shed new light on the contribution that smallholder farms make to world food production.

Evidence is mounting that smallholder farms, in other words, agricultural fields of less than around two hectares (ha) in size, make a substantial contribution to world food production. In addition, field size is known to be a good indicator of agricultural intensity, which could provide policymakers with valuable information around food security issues. Previous estimates of the total land area used for agriculture have suggested that smaller plots make up between 12% and 24% of the global total. A study led by IIASA researchers, however, puts the total land area of smallholder farms at 40% and has helped to fill some of the gaps in available information on global agricultural field size distribution.

The crowdsourcing campaign that provided the data for the study ran for four weeks starting in June 2017. Data was collected using the Geo-Wiki app, which takes high-resolution satellite imagery from Google Maps and Microsoft Bing and allows users to visually assess those images. In this case, users were asked to assess images of agricultural land.

A field was defined as any enclosed agricultural area, including arable and pastureland that could be separated by roads, permanent paths, or vegetation. Users could choose one of five field size categories – very large (greater than 100 ha), large (16-100 ha), medium (2.56-16 ha), small (0.64-2.56 ha), and very small (less than 0.64 ha). An instructional video and slides were used to train participants on how to use the app. Before being allowed to contribute to the official survey, users were asked to complete ten training images, with feedback given on each. Random 'control' images that had been expertly assessed were also randomly shown to users, and if these were incorrectly classified, the user received text feedback. This quality control feature was introduced to improve the quality of the results. Prizes were offered as an incentive to participate.

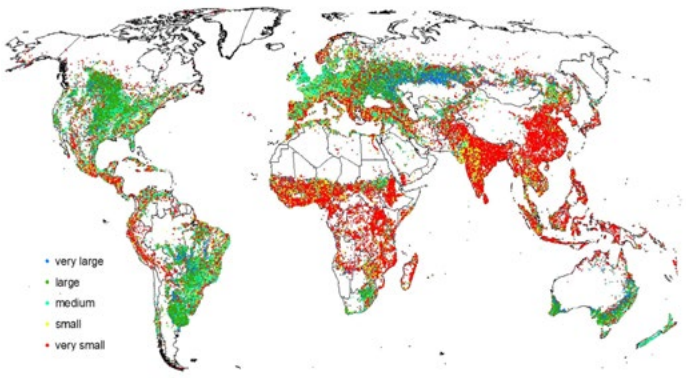

Figure 1: Global distribution of field sizes [1]

Each image was assessed by three users. A total of 130,000 unique samples were collected over the course of the four weeks, and the researchers used the 390,000 classifications (from three 'visits' to each site) to create a map and calculate the agricultural area proportions at the global, continental, and national levels. The study is the first to estimate field sizes at all three levels, and on a global scale. The resulting data set is much more detailed and denser than anything previously collected and is openly available for use in future research.

According to the researchers, this information will give policymakers an accurate overview of the global distribution of field sizes, thus providing better background knowledge for decision making related to food systems and agriculture, and ultimately supporting better policy decisions related to food security issues.

More information ar18.iiasa.ac.at/food-security

Transitions to New Technologies

Pioneering a new approach to systems transformations

One of the greatest challenges the world faces is how to limit climate change to below 1.5˚C. A groundbreaking IIASA study demonstrated the benefits of following an end-use, low energy demand (LED) strategy that does not rely on so-called negative emissions technologies.

IIASA hosts the database that the Intergovernmental Panel on Climate Change (IPCC) used to develop its Special Report on Global Warming of 1.5°C. It was while looking at this in 2017, that IIASA researchers noticed that each of the 400 global scenarios that could meet the 1.5°C target relied on negative emissions technologies. This realization resulted in a project that saw scientists from several research programs at the institute collaborating on the development of the LED scenario. Rather than focusing solely on climate change, the LED scenario instead incorporates the Sustainable Development Goals (SDGs) as a framework. The development process took just three months, attesting to the high degree of interdisciplinarity and cooperation between programs and researchers at the institute.

The LED scenario meets the Paris Agreement target of limiting global warming to 1.5°C by 2100 and is the first to do so by shrinking the energy system rather than relying on unproven negative emissions technologies, such as bioenergy with carbon capture and storage (BECCS). In the scenario, global energy use is reduced by 40% compared to today. The study [1] shows that dramatic transformations in the way we move around, heat and cool our homes, and buy and use devices and appliances in our cities can help raise living standards in the Global South to meet the SDGs while also remaining within the 1.5°C

target. According to the researchers, improved living standards for all need not come with a large increase in energy demand at the expense of the global environment.

The study had an exceptional impact on both science and policy. Altmetric statistics by *Nature* show the paper ranked in the top percentile of all articles included in their sample of 250,000 publications. The LED scenario was also adopted as one of the highlighted marker scenarios for the IPCC Special Report on Global Warming of 1.5°C and was instrumental in the planning for a special chapter on Demand, Services, and Social Aspects of Mitigation (Chapter 5, Working Group III) in the ongoing Sixth IPCC Assessment Report.

In terms of policy impact, the end-use demand perspective and the policy implications of LED have been highly influential in both international as well as climate policy circles, including an initiative by the Japanese government to present an alternative demand-side policy strategy for consideration at the G20 meeting. Further impacts are expected from a detailed policy interpretation brief (Figure 1) written in 2018 to be published in 2019. This policy brief also constituted part of the contract deliverables for the external ALternative Pathways toward Sustainable development and climate stabilization (ALPS) project with the Research Institute of Innovative Technology for the Earth (RITE) in Japan.

Figure 1: Examples of near-term policy actions to support a LED transition strategy for the domain of urban mobility.

More information ar18.iiasa.ac.at/systems-transformations

Risk and Resilience

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Supporting the policy discourse around Loss and Damage

In addition to mitigation and adaptation, the concept of "Loss and Damage" is considered a third pillar in the climate policy discourse. IIASA researchers provided evidence-based insight and proposals to facilitate a step-change in this highly politicized climate policy domain.

The discourse around "Loss and Damage" (L&D) has gained traction over the last few years. Supported by growing scientific evidence of man-made climate change amplifying the frequency, intensity, and duration of climate-related hazards, along with emerging evidence that adaptation may not be feasible in some regions, the Warsaw International Mechanism for Loss and Damage was established in 2013 and supported through the Paris Agreement in 2015. Despite some advances, the debate has been broad, diffuse, and even somewhat confusing. A book [1] published in 2018 as a joint effort by the Loss and Damage Network – an IIASA-led partnership between scientists and practitioners from various institutions around the globe – provides evidence-based insight into the L&D dialogue by highlighting state-of-the-art research conducted across multiple disciplines. The publication discusses applications in practice, and provides perspective on different policy contexts and salient policy options.

The volume identifies key propositions that hold potential for advancing the highly politicized debate. One proposition suggests that comprehensive risk analytics integrated with distributive and compensatory justice considerations provides an effective entry point for identifying a distinct L&D policy space and working towards a jointly acceptable position among negotiators from both developed and developing countries as there is currently no accepted definition of what L&D constitutes.

For the short-medium term, the authors' proposed framework takes a needs-based perspective for climate risk management beyond countries' ability to absorb risk. For the medium-longer term, they suggest the consideration of liabilities attributable to man-made climate change and its associated impacts. The authors developed the framework based on the principles of need and liability, and identified the policy space for L&D as composed of curative and transformational measures.

Transformational measures, such as managed retreat, have already received attention in discussions on comprehensive climate risk management, but according to the authors, curative action is less clearly defined, and more contested. They postulate that support for a climate displacement facility could be one policy option. For both measures, risk financing (such as climate insurance) emerges as an entry point for further policy action, as it holds potential for both risk management and compensation.

To quantify the L&D space for specific countries, the authors suggest building on a risk layering approach that segments risk and interventions according to tolerance. With many aspects of L&D being of immaterial nature, the authors propose that in principle, the current broad risk and justice-based approach can also be applied to issues like migration and the preservation of cultural heritage. The Intergovernmental Panel on Climate Change (IPCC) invited one of the book editors to coordinate the review of the state-of-the-art on L&D for its recent 1.5°C report [2].

More information ar18.iiasa.ac.at/loss-damage

Africa

The African continent faces a multitude of problems, which are often exacerbated by factors related to climate change. IIASA researchers engaged with stakeholders in several African countries aiming to encourage science based policymaking and address issues such as sustainable water management and agricultural practices, and examine trends in population and migration.

Selected highlights:

Encouraging science-based policymaking in East Africa

Serious gaming for risk communication and engagement

Forecasting world population and migration

Member countries:

Egypt | South Africa

Water

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Encouraging science-based policymaking in East Africa

A key goal of integrated water resources management is to balance supply and demand for all water users across different economic sectors while safeguarding the environment. IIASA research supports the incorporation of water science into policy, planning, and applied management issues.

Water scarcity intensifies when demand increases and availability in terms of quantity and/or quality decreases. The IIASA Water Futures and Solutions Initiative (WFaS) identifies and tests solution pathways across different economic sectors and supports the co-design of future development scenarios and possible solution options through stakeholder engagement. This provides important input for supporting mid- to long-term water management and planning based on informed decision making.

The initiative focused on East Africa with the extended Lake Victoria Basin as a key research area, aiming to understand the future water balance in the region toward 2050. The team used an integrated modeling framework combining the IIASA Community Water Model and the Extended Continental-scale Hydroeconomic Optimization model (ECHO), under two future development scenarios. Based on the East Africa Vision 2050 and the development visions of the East Africa Community member countries, the team developed an East Africa Regional Vision Scenario, while the second scenario, Business As Usual, is based on the Shared Socioeconomic Pathways (SSP2).

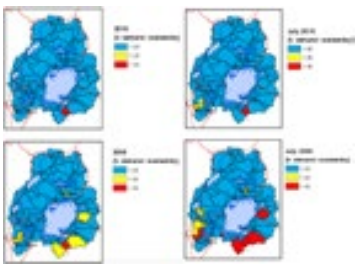

Figure 1: Change of the Water Exploitation Index for the Lake Victoria Basin from 2010 to 2050. The panels indicate how total water abstraction puts pressure on water resources. Severe water stress can occur in regions with an index over 40%.

Rapid economic development and population growth expected up to 2050 will lead to a sharp increase in water demand across all economic sectors. In this particular study area, much of the demand is expected to be offset by an increase in water availability due to climate change effects like increased precipitation, along with surface water runoff due to land use changes. According to the researchers, this may still lead to major water imbalances at the local scale and in particular areas of the studied basin.

The results of the two scenarios show moderate water scarcity when measured using the Water Exploitation Index (Figure 1) and high water scarcity when measured using the Water Crowding Index (Figure 2). Uncertainties in the modeling results are mainly attributed to the projection of various drivers such as irrigation area expansion, future water use efficiency parameters, and climate change effects resulting from the use of general circulation models.

The project is funded by the Austrian Development Agency (ADA) and the Austrian Federal Ministry of Sustainability and Tourism. The results are helping the Lake Victoria Basin Commission and its member states (Burundi, Kenya, Rwanda, South Sudan, Tanzania, and Uganda) to make science based water resource management decisions. Stakeholder workshops presented as part of the project attracted researchers and practitioners from across the region [1]. In December 2018, the results were also presented and discussed at a workshop that included training participants on the analysis and interpretation of the modeling results [2].

The team will expand their work through a project titled, Scaling out Resilient Water and Agricultural Systems (scaleWAYS), which looks at up-scaling options for water and land management practices for the resilient and sustainable intensification of agricultural production and food systems in the extended Lake Victoria Basin [3].

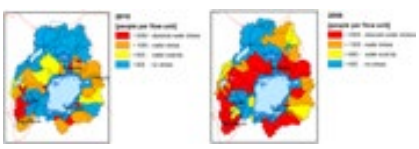

Figure 2: Change of the Water Crowding Index for the extended Lake Victoria Basin from 2010 to 2050. Below 1,700m³/capita/year water stress appears regularly, below 1,000 water scarcity is a limitation to economic development and human health, and below 500 water availability is a main constraint to life.

More information ar18.iiasa.ac.at/policy-east-africa

Risk and Resilience

Serious gaming for risk communication and engagement

IIASA researchers develop and carry out serious games and simulations around the world to engage policymakers, businesses, communities, academics, and others in exploring the challenges of reducing disaster risk, building resilience, and ultimately contributing to sustainable development.

In 2018, floods, wildfires, tsunamis, and other hazards were responsible for economic losses of US$225 billion and sadly also caused the deaths of more than 10,000 people. The UN International Strategy for Disaster Reduction's Sendai Framework calls for substantially reducing disaster risk and building resilience at all levels by 2030. This is critical for achieving the UN Sustainable Development Goals.

The following games have been played in numerous locations: Flood resilience (blue), Narubu (red), NEXUS (green), Forest@Risk (orange).

Effective communication and engagement with citizens, businesses, and policymakers are key to helping stakeholders overcome the challenges they face in taking pro-active measures to reduce risk and enhance community resilience. One challenge is the complex nature of disaster risk, which is often embedded in "wicked" contexts where both the nature of the problem and the preferred solution are strongly contested. A related challenge is overcoming the public good nature of preventive measures – the "free rider" problem. These and many other challenges can be effectively understood and ultimately addressed with the use of serious games, which can provide a simulated real-world environment for experiential learning. In this way, participants learn about the complex structure of the problem at hand, including the social complexities of interactions among multiple stakeholders with conflicting agendas, problem frames, interests, and worldviews (wicked problems) [1].

IIASA researchers conducted the first comprehensive review of 45 non-commercial disaster-risk-management (DRM) games [2], which showed their potential in helping raise risk awareness, identifying hazards, undertaking preventive actions, triggering empathy and perspective-taking, and providing a rich social experience with players collaboratively approaching and solving problems. Some limitations identified in the review included difficulties in incorporating cultural diversity and gender equality, and the necessity of strong facilitating skills.

Building on this experience, the team designed its own user-tailored games. Examples include:

- A flood resilience game that helps practitioners experience, explore, and learn about flood risk and the resilience of communities in river valleys, and identify novel policies and strategies that improve flood resilience.
- The Narubu game of many voices, which engages participants to experience the inherent difficulties of framing and solving 'wicked' water resource and disaster issues, and the limitation on evidence-based decision making in a context of multi-stakeholders with diverse worldviews.
- Forest@Risk confronts players with the challenges of environmental disasters (earthquakes and floods) faced by vulnerable forest-dependent communities to explore and learn how to simultaneously manage multiple public and common goods, emphasizing the importance of internal agreements and trust.
- Players in the Nexus Game take on the roles of policymakers tackling interconnected water-food-energy nexus challenges in a transboundary setting under drought and flood risks.

IIASA carried out DRM game sessions across Africa, America, Asia, and Europe with participants from public and private sectors, international organizations, civil society organizations, and academia. The team is also piloting their use in real-world stakeholder engagement and knowledge co-production processes.

More information ar18.iiasa.ac.at/risk-communication

World Population

Forecasting world population and migration

When fertility levels are low, as is currently the case in Europe, international migration becomes the main factor influencing population growth. However, research shows that in terms of economic consequences, the size of the labor force and productivity matter more.

A book published in 2018 by researchers from the Centre of Expertise on Population and Migration (CEPAM) – a collaboration between IIASA and the European Commission's Joint Research Centre (JRC) – examined potential future scenarios of population trends across the world [1]. The team looked at the population outcomes for 201 different countries, based on three different migration scenarios for each country, in addition to various fertility, mortality, and education scenarios.

Previous demographic assessments have only considered age and sex in population trends, while this study also factored in educational attainment and labor force participation for EU member states. According to the researchers, migration should be seen as an integral part of population dynamics, which is why in their analysis, they considered it in the context of alternative possible scenarios for all countries of the world over the rest of this century.

In the medium scenario, for instance, world population would continue to increase until 2070–2080, reaching 9.7 billion before starting to decrease. This increase is higher than previously thought, largely due to a faster decline in child mortality in Africa. An alternative scenario assuming rapid social development, and especially better levels of education for women, would lower fertility rates with a peak population

of 8.7 billion reached in 2055–2060. Stalled social development and lower levels of education on the other hand, result in higher fertility rates and the population continuing to climb over the century, reaching 13.6 billion in 2100.

These effects will of course not be the same for all regions of the world. Under the medium scenario, for example, the population of the European Union will marginally increase to around 512 million people by 2035, largely due to immigration. Following this initial increase, there will be a decline as fertility rates are low with significant aging. Interestingly, the findings indicate that the available labor force does not necessarily diminish if female participation increases.

In Sub-Saharan Africa, the population under the medium scenario is likely to double by 2060, to around 2.2 billion people. With stalled social development and a lack of expansion in terms of education, this could even rise to 2.7 billion, which would in turn lead to widespread poverty and high vulnerability to climate change, with serious implications for potential emigration.

The scenarios developed will help policymakers face a broad range of challenges, from the economic consequences of population aging, to setting development priorities. The results highlight that within certain bounds, future trends in population are not a given and can still be influenced by policies in the longer term, while migration itself can most easily be influenced by policies in the short term.

More information ar18.iiasa.ac.at/forecasting

Americas

IIASA has a long-standing relationship with its member countries in the Americas. In 2018, IIASA researchers participated in a number of projects to explore issues facing both developing and developed countries in the region, including possible solutions for cleaner energy, limiting deforestation, and analyzing potential shocks to financial systems.

Selected highlights:

Coal jobs vs. climate change mitigation

Analyzing potential shocks to financial systems

Understanding ecological resilience through network science

Member countries:

Brazil | Mexico | USA

Ecosystems Services and Management

Coal jobs vs. climate change mitigation

Contrary to how it is often portrayed in the public discourse, IIASA-led research has found that the goals of coal sector employment and climate change mitigation can actually be aligned.

As the need for solutions to the impending consequences of rising global temperatures has become increasingly urgent, concerns have been raised about the loss of jobs if current technologies like coal-fired power plants are phased out. In a 2018 IIASA-led study, researchers modeled the transformation of the US coal sector until 2050. According to the results, the most optimal strategy for meeting the 2050 emission reduction targets consistent with staying below 2°C warming, is through the early deployment of bioenergy with carbon capture and storage (BECCS) and by replacing 50% of aging coal plants with natural gas plants. This would not only retain the current 40,000 jobs in the US coal industry, but would also create 22,000 new jobs in related sectors by the middle of this century.

Carbon dioxide removal (CDR) technologies that aim to remove and sequester excess carbon from the atmosphere, have been identified as an important part of the response to climate change. Among them, BECCS combines carbon capture and storage, in which CO_2 is collected from large emission sources such as power plants and injected into underground geologic formations, with the use of plant-based materials (biomass) as a source of fuel. The future role of BECCS and the scale of its deployment are still controversial, but the results of this study show that acting now and investing in this emission-mitigating strategy can be beneficial for employment in the sector.

The researchers studied the major processes and steps involved in the potential energy supply chains for the US coal fleet. Specifically, they looked at the supply of biomass resources from managed and certified US forests and the design and cost of infrastructure for transporting and injecting CO_2 into appropriate geological sites, taking into account that biomass must be grown and harvested in a sustainable way to be considered carbon-neutral and thus lead to negative emissions.

The team used a number of different models to analyze existing data, including two from IIASA, the Global Forest Model (G4M), which looks at income from forestry and alternative land uses, and the BeWhere model, which optimizes the technology development of US coal power plants, including feedstock logistics. They also used the Jobs and Economic Development Impact model (JEDI) from the National Renewable Energy Laboratory (NREL), to estimate the employment impacts of technology development.

According to the researchers, repurposing US coal plants presents a rare opportunity to address both emission mitigation and job creation if the right technology change is adopted. They propose that, rather than arguing that climate change mitigation is simply necessary, policymakers should inform the coal sector that such strategies entail employment opportunities.

More information ar18.iiasa.ac.at/coal-climate-change

Evolution and Ecology

Analyzing potential shocks to financial systems

Understanding the dynamics of an emerging economy like Mexico requires insight into the shocks that could impact its external financial account and particularly its stock market. IIASA researchers analyzed interactions between risk and financial interrelations to provide policy recommendations aimed at lessening or avoiding risk.

Economic and financial interrelations in especially developing economies are complex and require innovative models to analyze external and

internal shocks. In their study [1], IIASA researchers set out to determine the main shocks that affect the capital flow dynamics in Mexico. They also modeled the country's complex economic system using a system-dynamics methodology focusing on the stock market [2].

In an emerging market economy (EME) like Mexico, the current account may be vulnerable to external shocks and reversals of capital flows. It is therefore fundamental to determine external factors such as global risk, liquidity, economic activity, and the foreign interest rate, as well as internal factors like domestic economic activity, inflation, the domestic interest rate, and the exchange rate, that affect the financial account. A country's financial account comprises foreign direct investment (FDI), as well as portfolio and other investments, where FDI could be a catalyst for economic growth. For that reason, it is important to understand the push and pull factors that determine the capital flows and to avoid or reduce external shocks.

The researchers explain that under highly uncertain conditions, external shocks raise risk because the push factors are beyond the control of EMEs, although they can be mitigated. In the capital flow recipient country, risk can be exacerbated if there are account deficits, inflationary pressures, and appreciation of real exchange rates. This could in turn induce systemic failures. To avoid damage to the economy or the possibility of a financial crisis spreading to EMEs as a result of external financial and economic turbulence like during the financial crisis of 2008, it is essential to improve the pull factors or the prevailing economic conditions in each country, and for EMEs to have economic policies that mitigate external shocks.

The researchers found that global liquidity, the federal funds rate, and global risk are the main determinants of portfolio investment by foreign investors. The results further revealed that in Mexico, an increase in global risk leads to lower portfolio investment in private sector securities and higher portfolio investment in public sector securities, as these are less risky.

The Mexican financial account and stock market provide a wealth of information about the network dynamics of both the external and financial sector. To this effect, IIASA researchers also used a macroeconomic equilibrium model to show the importance of the stock market in the economic growth of an EME.

These studies highlighted the importance of understanding how external and internal shocks affect capital flows to Mexico and the stock market. Based on their results, the researchers provided economic policy recommendations that could reduce risk and contribute to developing a healthy external and financial sector in Mexico as well as in other EMEs.

More information ar18.iiasa.ac.at/financial-systems

Advanced Systems Analysis

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Understanding ecological resilience through network science

People depend on ecosystems for food and other environmental services. In 2018, a number of IIASA projects focused on methods from network science that link resilience with the structure and interconnectedness of these systems.

The concept of ecological resilience, which is also a necessary condition for sustainability, was first introduced by former IIASA Director CS (Buzz) Holling in the early 1980s and has since been extensively studied by many scholars at the institute and elsewhere.

According to a new book co-written by IIASA researchers, achieving a sustainable world will require a paradigm shift in the way we approach life sciences and ecology [1]. The authors state that 'life' is not best viewed as a property of an organism, but should rather be seen as a property of an integrated system of organisms, ecosystems, and the biosphere. They further argue that the reductionist approach of treating life as a singular model, rather than as a system is partially responsible for the global environmental problems we face today. The book proposes six principles of holistic life science, including that it must be centered on the value of life, balance holistic and reductionist approaches, be able to model and understand complex life systems, and recommend actions for interacting with those systems.

To provide decision makers with clear indicators of resilience, IIASA researchers looked into novel network-based resilience concepts and measures from ecology that can also be applied to socioecological systems [2]. The concept of resilience actually already appears in the management principles of decision makers. A case study for the United States Bureau of Ocean Energy Management [3], for example, revealed how the bureau adopted a system that seeks to mimic and anticipate environmental change to manage for the resilience of marine ecological resources and their associated social elements. The study shows that a dynamic management framework that couples social and ecological systems can facilitate the efficient and effective utilization of resources, reduce uncertainty for decision makers, and lead to more defensible decisions on resources.

The network view on ecosystems was also innovatively used in a study aimed at understanding the use of eco-space and biodiversity [4]. The researchers looked at ecosystems in terms of the reactions that occur in response to changes in the system and then act as catalysts for other changes or interactions. They found that niche emergence, in other words, the ability of a species to evolve to adapt to their new circumstances, rather than niche partitioning where competing species use the environment differently to help them coexist, is what mostly drives ecological diversity.

Apart from engaging in research, IIASA scientists were also involved in the production of educational material for other scientists and the general public in 2018. This included editing the 2nd edition of the Encyclopedia of Ecology [5] and co-authoring several articles in Elsevier's Reference Module in Earth Systems and Environmental Sciences, an online database containing reference articles on major concepts and notions in particular scientific areas [6, 7, 8].

More information ar18.iiasa.ac.at/ecological-resilience

Asia

Over the years, IIASA has built strong collaborative relationships with many institutions in its member countries across Asia. Researchers from the institute regularly engage with colleagues at partner institutions to provide systems analysis tools and collaborate on issues like air quality, sustainable energy systems, and water resource management, aiming to promote informed policymaking in the region.

Selected highlights:

Informing clean air policies

Towards better air quality management in Vietnam

Accounting for diversity in population projections

Member countries:

China | India (Observer) | Indonesia | Iran | Israel | Japan | Korea | Malaysia | Vietnam

Air Quality and Greenhouse Gases

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Informing clean air policies

Breathing clean air, the most basic human need, has become a luxury in many parts of the world. IIASA researchers contributed to a report representing the first comprehensive scientific assessment of the air pollution outlook for Asia and the Pacific.

Around 4 billion people living in the Asia-Pacific region – this is 92% of the population – are exposed to levels of air pollution that pose a significant risk to their health. Worldwide approximately 7 million people annually die prematurely from air pollution related diseases, with about 4 million of these deaths occurring in Asia-Pacific.

Researchers from IIASA led the modeling and quantitative analysis [1, 2] of the study that underpins the report and helped to identify simple and cost-effective measures that could deliver benefits across sectors. During their analysis the team realized that some measures have larger than expected potentials to reduce air pollution, while others generally thought to be effective make only a small difference. Knowing this could improve the effectiveness of policies. The work also considers the region's considerable diversity, showing that the identified measures are not equally appropriate for every part of Asia-Pacific, which means that they must be tailored, prioritized, and implemented according to national conditions.

The selected measures can be grouped into three categories. The first concerns conventional emission controls focusing on emissions that lead to the formation of fine particulate matter (PM2.5), in other words, particles such as dust, soot, and smoke that result from, for instance, the burning of fuel. Measures in this category includes activities like increased emissions standards and controls on vehicles, power plants, and large- and small-scale industry. The second category focuses on further air-quality measures aimed at reducing emissions that lead to the formation of PM2.5 and are not yet major components of clean air policies in many parts of the region. This includes actions like reducing the burning of agricultural and municipal solid waste, preventing forest and peatland fires, and proper management of livestock manure. Measures in the third category contribute to development priority goals with benefits for air quality. This includes using renewable energy for electricity generation, providing clean energy for households, improving public transport, and promoting the use of electric vehicles.

Millions of lives could be saved and one billion people living in Asia could be breathing clean air by 2030 if the simple and cost-effective measures outlined in the report are implemented. Specifically, effectively implementing the 25 measures would result in a 20% reduction in carbon dioxide and a 45% reduction in methane emissions, preventing up to a third of a degree in global warming. Resulting reductions in ground-level ozone could also reduce crop losses by 45% for maize, rice, soy, and wheat combined. According to the report, this will not only deliver substantial benefits to human health, food production, environmental protection, and climate change mitigation, but a basket of co-benefits that includes savings on pollution control will also accrue.

More information ar18.iiasa.ac.at/clean-air

Air Quality and Greenhouse Gases

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Towards better air quality management in Vietnam

A collaborative research project between IIASA and the Vietnam Academy of Science and Technology has given rise to a multidisciplinary research community in Vietnam that can provide decision makers with comprehensive scientific support on air quality management.

A cooperative scientific project on air quality management in Vietnam between IIASA and its Vietnamese National Member Organization, the Vietnamese Academy of Science and Technology, reached an important milestone in 2018 with the publication of its first year's progress report. During the first year of the project, the IIASA Greenhouse Gas – Air Pollution Interactions and Synergies (GAINS) model was adapted to the Greater Ha Noi/Red River Delta area and surrounding regions, and an initial set of data compiled from publicly available statistics and studies. A report [1] on this phase of the project was presented at a workshop in Hanoi towards the end of 2018, which also marked the formal launch of the GAINS-Vietnam model.

The report highlights that air pollution is a real problem in Vietnam, with the measured annual mean concentrations of fine particulate matter (PM2.5) in the air exceeding the global guidelines of the World Health Organization by a wide margin. PM2.5 refers to particles in the atmosphere that have a diameter of less than 2.5 micrometers – about 3% of the breadth of a human hair. These can come from various sources including power plants, residential wood burning, airplanes, motor vehicles, and forest fires. Because they are so small and light, these particles stay in the air longer, thus increasing the chances of humans and animals experiencing adverse health effects from inhaling them.

According to the researchers, Ha Noi's air quality could deteriorate even further in the future due to the anticipated increase in economic activity, despite the currently adopted policy measures. They caution that, without additional policy measures particulate matter concentrations in northern Vietnam could be 25-30% higher in 2030 than in 2015. This implies that almost 85% of the population in northern Vietnam would be exposed to air quality that does not conform to the national ambient air quality standard.

The analysis also shows that effective improvements of specifically Ha Noi's air quality will require coordination with neighboring provinces because, while about one third of PM2.5 exposure in Ha Noi originates from emission sources within the same province, the majority is imported from outside. This means that if restricted to the Ha Noi province, even the most stringent emission control measures will be insufficient to effectively reduce ambient pollution levels in the city.

Although further work will be necessary to refine the GAINS-Vietnam tool, the initial findings are highly relevant for air quality management in the country. Cost-effective strategies need to combine technical emission controls with policies that promote structural changes, such as energy efficiency improvements and a transition to cleaner fuels. Once fully implemented, the GAINS-Vietnam tool could help to identify effective portfolios of measures that take into account the costs, benefits, and political economy of policy interventions.

More information ar18.iiasa.ac.at/air-vietnam

World Population

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Accounting for diversity in population projections

Researchers from IIASA and the Asian Demographic Research Institute have shown that explicitly accounting for differences within populations significantly influence future population projections. Their work contributes to current debates in population forecasting and more broadly to social and economic forecasting models in general.

Users of population data in many sectors commonly use data without considering differences in the behaviors of populations in different regions of a country. Researchers working on a collaborative study of population forecasts for India however, realized that, as India is an extremely heterogeneous sub-continent, it should not be treated as a uniform entity simply because it is one nation.

To account for the diversity between different areas of the country, the team designed a study that pioneered a five-dimensional model of differences in the Indian population, including rural or urban place of residence, state, age, sex, and level of education. The model was used to show the population projection changes within scenarios that combine different levels of these factors, and revealed that forecasts over the coming decades strongly depend on which sources of differences between regions are explicitly included in the model.

The results show that a much higher population projection emerges from a model that combines projections for individual Indian states as opposed to the overall national projection, since states with higher fertility rates eventually add up to a higher national population projection. If the projection is carried out while only explicitly accounting for age and sex, influential factors like higher levels of education, which is in turn associated with decreased fertility, are omitted. The researchers explain that because education levels have increased over time across all of India, and are associated with a lower fertility rate, the same projection may predict

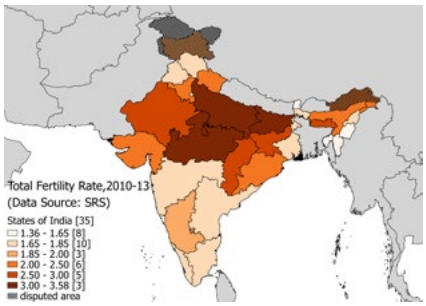

Figure 1: Total fertility rate across states of India for 2010-2013 (Data source: SRS).

a drastically smaller population when accounting for education and increasing urbanization. When both effects are combined, the influence of education appears to dominate, resulting in a lower population projection.

This prompted a further investigation into future education trends, which revealed that if education were to stay at its current level, the population would increase slightly more than if education improved over time. The difference between projections highlights the critical importance of deciding which demographic measures to include in a projection model, and at what rate of change. At the most general level, the research reveals the importance of considering differences within sub-national populations, and recognizing that they are at different stages of a general development. The team conclude that in addition to age and sex, education should be routinely included in population forecasts because of its well-established implications for improving the economy and quality of life, while reducing population growth and mortality rates.

The researchers believe that continuously improving population projections can help planners and support increased investment in education and human resources as countries continue to develop.

They have invited decision makers to approach them for collaboration on more future narratives, more in-depth analyses, or to use their research as input for policy work.

More information ar18.iiasa.ac.at/diversity

Europe

IIASA research has been providing science-based insights to inform policy at national and regional levels across Europe since its inception in 1972. In 2018, IIASA researchers continued their work on issues affecting countries in the European neighborhood by, among others, exploring the risks and opportunities of decarbonization from a financial perspective, and advocating the mainstreaming of extreme risk into fiscal and budgetary planning.

Selected highlights:

National energy modeling and capacity development

Mainstreaming extreme risk into fiscal and budgetary planning

The finance risks and opportunities of decarbonization

Member countries:

Austria | Finland | Germany | Netherlands | Norway | Russia | Sweden | Ukraine | United Kingdom

Advanced Systems Analysis

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Enhancing resilience to systemic risk

The chance that the collapse of one institution leads to the collapse of an entire system is known as systemic risk. IIASA researchers investigated this emergent phenomenon in networks and suggested approaches to its management.

The financial crisis of 2008 was triggered by the failure of a single bank. It is however not only financial firms that contribute to systemic risk in monetary systems, but also non-financial firms such as vehicle manufacturers and energy companies. A study [1] by researchers from two IIASA programs reconstructed the financial network of nearly all commercial enterprises (49,363 firms) and banks (796) in Austria, making this the most comprehensive financial network ever analyzed.

The team employed a method known as DebtRank, which revealed that, although large banks are the institutions with the highest DebtRank in the Austrian economy, the eighth most systemically important firm is non-financial. The results show that if this firm defaulted, up to 39% of the Austrian economy would be affected. The other systemically important firms identified came from multiple sectors, and were not all large. A number of mid-sized firms that are systemically important in the Austrian economy were distinguished and it emerged that non-financial firms actually introduce more systemic risk than the financial sector.

These findings support introducing a regulation similar to the Basel III framework, which was imposed on banks to increase bank liquidity, on non-financial firms as well. The study further suggests that bank stress tests should go beyond current practices to consider not only inter-bank feedback effects, but also effects between banks and the real economy.

As systemic risk is a network property, it can also be decreased by restructuring a network's connectivity. IIASA researchers looked at the most prominent measures for managing both individual (non-systemic) and systemic risks to better understand how a joint integrated regulatory framework can be developed to increase the resilience of both [2]. Specifically, they advocated for an intelligent combination of hedging instruments (e.g., insurance) to increase resilience to individual risk with measures to change system network linkages by, for example, restricting the speculative behavior of banks.

Another aspect not typically considered in systemic risk research concerns the nature of the trigger. Banks can, for instance, experience gradual increases in stress, eventually leading to default, while natural hazards leading to cascading losses can be graduated in their severity. In their paper [3], IIASA researchers showed how the risk of gradual and dependent trigger events could be estimated using statistical constructs called copulas to quantify the increasing dependency between higher-impact event probabilities.

An additional study using copulas to assess Austria's drought risk [4] further showed that subsidized insurance would need 20% more funding in the future due to climate change. While average yields of the most important crops are expected to increase, the risk of extreme droughts with cascading impacts also increases.

More information ar18.iiasa.ac.at/systemic-risk

Risk and Resilience

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Mainstreaming extreme risk into fiscal and budgetary planning

Climate change is having a visible impact on biological, physical, and human systems and this trend will likely continue into the future. Longer-term fiscal assessments will be crucial for public authorities to be adequately prepared for increasing climate-related risks.

Studies show that 43% of all recorded climate-related and geophysical disasters between 1998 and 2017 were floods, representing 23% (or US$656 billion) of related economic losses. Austria, in particular, has been subject to recurrent large-scale flooding leading to losses of several billion Euros in 2002, 2005, and 2013. Although Austria has a disaster fund in place to deal with impacts and implement preventive building measures, the fund's setup is not based on longer-term planning procedures.

The country is however not alone in employing a static approach to public disaster risk financing. While aging-related costs are often perceived as major drivers of fiscal pressure, concerns over climate-related public expenditure have received comparatively little attention. Longer-term drivers of extreme climate risks include changes in hazard frequency and intensity due to climate change, as well as socioeconomic trends like urbanization, population aging, and land-use changes. Longer-term fiscal assessments of climate extremes must integrate these underlying risk drivers.

IIASA researchers used the Shared Socioeconomic Pathways (SSPs) scenarios as a bridging concept to link the assessment of the public cost of demography- and climate-related expenditures. They developed a climate risk mainstreaming methodology using a stochastic debt model to assess potential fiscal flood risk in Austria. The baseline modeling results show that public debt in the country is estimated to increase from the current level of 84.5% relative to GDP in 2015, to 92.1% in 2030. Macroeconomic variability adds further risk to the country's baseline public debt trajectory, while the estimated public contingent liability due to expected flood risk is small relative to the size of economy.

The team also evaluated the likely impact of climate extremes on the sustainability of Austria's disaster fund and found that the current setup is sufficient to cover the cost of frequent-and-low impact floods but is likely insufficient to deal with the rising risk of extreme floods. The study calls for further discussions regarding reforms of the fund. IIASA researchers continue to work with the Austrian Ministry of Finance and their recommendations, which were drafted in collaboration with Austrian colleagues, have led to a first recognition of extreme weather risks in Austria's longer-term budget analysis and in the country's 2018/2019 budget report.

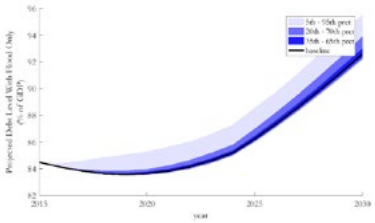

Figure 1: Stochastic debt trajectories for Austria under SSP2 scenario up to 2030. Showing 5th to 95th percentiles [1].

As many EU member states are in the early stages of designing climate policy strategies, the proposed method can support the mainstreaming of climate-related concerns into longer-term fiscal planning across the EU. This research expands the institute's work on fiscal resilience from the developing world, where IIASA has advised over 20 finance ministries.

More information ar18.iiasa.ac.at/budgetary-planning

Energy

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The finance risks and opportunities of decarbonization

If financial markets become more long-term oriented, they could potentially become a catalyst for action on sustainability. In 2018, IIASA scientists collaborated with international banks and researchers from other institutions to assess the financial implications of deep decarbonization strategies.

Researchers from the institute collaborated with a consortium of 16 leading banks from four continents convened by the UN Environment Program Finance Initiative (UNEP FI) to publish a jointly developed methodology to increase banks' understanding of how climate change and climate action could impact their business. This understanding is fundamental to enabling banks to be more transparent about their exposure to climate-related risks and opportunities in line with the Task Force on Climate related Financial Disclosures (TCFD). It will also inform banks' strategies to contribute to and benefit from low-carbon economic transition, and help them engage and support their customers to that effect. This is important because the climate-related risks and opportunities that banks face arise primarily from their services to clients.

The IIASA team contributed to the methodology development and provided detailed scenario data from the MESSAGEix-GLOBIOM integrated assessment model, which formed the basis of the report, together with the Potsdam Institute for Climate Impact Research's REMIND-MAgPIE model. The team developed risk factor pathways for individual economic sectors in different world regions. Three scenarios were used in the project: a baseline, and deep decarbonization pathways consistent with 2°C and 1.5°C warming. These scenarios were developed within the context of the ongoing European Commission

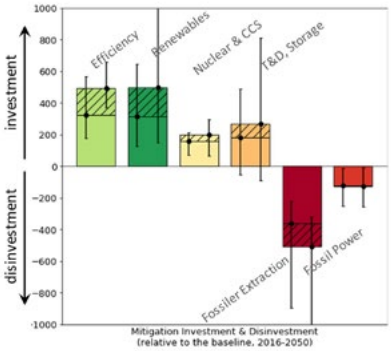

Figure 1: Mitigation Investments and Disinvestments of reaching the climate objective of 2°C and 1.5°C temperature change. Cross-hatched areas indicate additional investment or disinvestment of 1.5°C compared to 2°C. [1].

Horizon 2020 research project CD-LINKS, which is coordinated by IIASA.

In another project, IIASA scientists led an international consortium that analyzed the required investments for meeting the targets of the Paris Agreement. The study [1] found that a fundamental transformation of the global energy system can be achieved with a comparatively modest increase in overall investments. However, a radical shift of investments away from fossil fuels and toward renewables and energy efficiency is needed (Figure 1) along with dedicated investments into measures to achieve the UN Sustainable Development Goals (SDGs).

To keep global temperature rise to 1.5°C or 2°C, investments in low carbon energy and energy efficiency will likely need to overtake investments in fossil fuels as early as 2025 and then grow far higher. The low carbon and energy efficiency "investment gaps" calculated by the researchers are striking. To meet countries' nationally determined contributions (NDCs), an additional US$130 billion of investment will be needed by 2030, while to achieve the 2°C target the gap is $320 billion, and for 1.5°C, it is $480 billion. These investment figures represent more than a quarter of total energy investments foreseen in the baseline scenario, and up to half in some economies such as China and India.

In addition to the above efforts, IIASA scientists also participated in the Scientific Advisory Group of the Science Based Targets initiative, contributed to the Integrated Assessment Modeling Consortium (IAMC) Working Group on Climate Finance, and participated in several workshops with the financial sector.

More information ar18.iiasa.ac.at/decarbonization

Advanced Systems Analysis

The Advanced Systems Analysis Program develops, tests, and makes available new quantitative and qualitative methods to address problems that arise in the policy analysis of complex socioenvironmental systems. The program's activities focus on methods used to support decisions in the presence of uncertain and volatile input data, ambiguous stakeholder interests, and complex underlying systems.

Program website
Publications
Staff
Scientific recognition

Selected highlights:

Enhancing resilience to systemic risk

Supporting decision making under uncertainty

Exploring the impact of digitalization

Understanding ecological resilience through network science

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More information ar18.iiasa.ac.at/systemic-risk

Exploring the impact of digitalization

With the advent of the internet and the expansion of the digital economy, an increasing portion of consumption cannot be evaluated in monetary terms and attributed in the traditional way. IIASA research explored the impact of digitalization on economies.

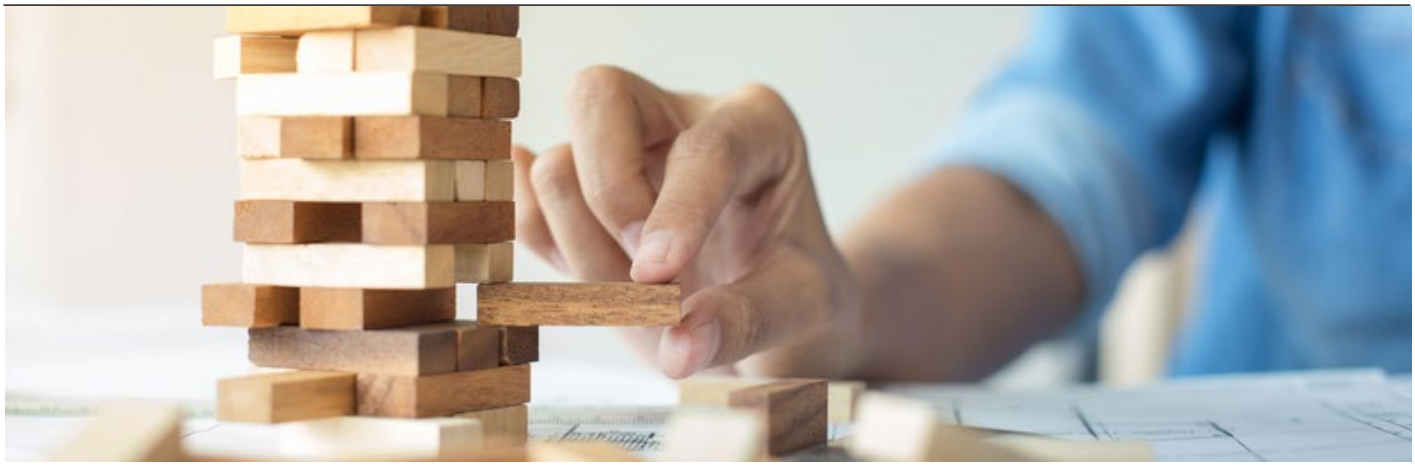
Governments are tasked with devising economic policies to improve the population's wellbeing, which is traditionally indicated by per capita consumption. Many services provided through the internet, however, are paid for by companies advertising their products – consumers do not pay for it themselves. As a result, this consumption is not reflected in national economic statistics including the country's gross domestic product (GDP). Services provided through the internet that are not priced and monetized in the traditional way, and therefore not part of the national GDP, are referred to as un-captured GDP.

IIASA research highlighted the phenomenon of un-captured GDP and demonstrated the limitations of current national statistics to properly account for those. The problem of un-captured GDP emerges because market prices do not necessarily reflect longitudinal changes in the quality of products. The study [1] reviewed several approaches that could be used to correct market prices, and hence the national statistics, to account for un-captured GDP. The paper highlights the significant shift in consumer preferences from purely economic functionality to supra-functionality beyond economic value. Further research [2] focused on Finland and Singapore – both world leaders in Information and Communications Technology (ICT) – and contrasted un-captured GDP trends between the two countries to explain the difference in their economic growth rates and welfare. An empirical analysis revealed that innovation of especially products and services of an aesthetic or intellectual nature have created un-captured GDP in Finland.

IIASA researchers also looked at the apparent productivity paradox in the digital economy, where for the last 15 to 20 years the ICT sector has become more interactive, integrated, and seamless. This interconnectedness is expected to create many new opportunities. However, while technological progress historically implied economic growth, in the internet era it seems that this is not the case. A possible explanation might be the two-faced nature of ICT: while capital accumulation in the ICT sector increases the price of products, the abundance of the internet actually decreases it, resulting in an overall decline of the price over time. Another IIASA study [3] empirically examined and confirmed this hypothesis.

Global ICT firms are embracing digital solutions and restructuring their business models toward more competitive digital business strategies. IIASA researchers [4] analyzed digital business solutions in 500 global ICT firms from 2005 to 2016 and discovered that research- and development-intensive firms have fallen into a trap in ICT advancement, resulting in a decline in their marginal productivity. This could be due to increasing dependency on un-captured GDP. As a result, these firms want to harness soft innovation resources and activate a self-propagating function that induces functionality development through sophisticated digital business strategies in response to un-captured GDP. This work highlights the significance of new, open, platform-based innovations in the digital economy.

More information ar18.iiasa.ac.at/digitalization



Supporting decision making under uncertainty

The need to account for uncertainty when making decisions is at the core of systems analysis, be it for decisions around crop allocation or the choice of technologies in the energy and water industries.

Decisions supported by optimization models are typically sensitive to model parameters like precipitation, temperatures, and market prices, which are naturally highly uncertain. Due to the non-linear dependence of solutions on uncertain parameters, naïve scenario-based analysis is often misleading in producing reliable policy advice. IIASA researchers and collaborators from China demonstrated how much optimal solutions might vary in different scenarios in a case study of coal and agriculture production in Shanxi, China [1].

Researchers from the institute have been developing and prototyping a technique as an alternative to the scenario-based approach for decades. The resulting technique can be used to devise robust solutions tailored to dealing with uncertainty associated with the risks of catastrophic natural disasters like floods or earthquakes. The team reviewed and highlighted the value of this methodology for a general audience [2]. The work demonstrates that pro-active risk mitigation measures combined with an intelligent approach to setting resources aside, could build adaptive capacities for actions after an

event. This can significantly reduce the overall burden on national economies and strike a healthy balance between economic growth and security.

IIASA researchers also participated in the development of a portfolio model to support the selection of strategic actions in corporate decision making when information about the input uncertainty is incomplete and may depend on selected actions [3]. In their paper, the authors also present a case study where the model helped a group of globally operating Nordic steel and engineering companies to build a platform ecosystem strategy that accounts for uncertainties related to markets, politics, and technological development.

In a separate study, IIASA researchers suggested a way to improve a prominent decision-support approach known as "many-objective robust decision making" (MORDIM) [4]. They showed that incorporating a systematic scenario selection procedure in the search phase, not only makes solutions more robust, but also results in an increased trade-off variety.

Another approach to dealing with decisions under uncertainty is based on the idea of "guaranteed" controls from mathematical control theory, which requires the set-up goal to be achieved for any realization of uncertainty. The methodology of attainability domains (or reachable sets) is helpful to derive such "guaranteed" controls. IIASA researchers developed a numerical algorithm that is able to solve general "guaranteed" guidance problems for linear dynamical systems with incomplete information about the initial state of the system [5].

Attainability domains were also used to analyze models representing diffusion processes [6]. Such models can be helpful in analyzing opinion dynamics across a network of people, or the dynamics of labor and capital flows over a network of countries. The team employed a probabilistic framework to represent diffusion in networks and provided a tractable and efficient way for controlling the network dynamics by means of external controls and alterations in the network topology.

More information ar18.iiasa.ac.at/uncertainty

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Understanding ecological resilience through network science

People depend on ecosystems for food and other environmental services. In 2018, a number of IIASA projects focused on methods from network science that link resilience with the structure and interconnectedness of these systems.

The concept of ecological resilience, which is also a necessary condition for sustainability, was first introduced by former IIASA Director CS (Buzz) Holling in the early 1980s and has since been extensively studied by many scholars at the institute and elsewhere.

According to a new book co-written by IIASA researchers, achieving a sustainable world will require a paradigm shift in the way we approach life sciences and ecology [1]. The authors state that 'life' is not best viewed as a property of an organism, but should rather be seen as a property of an integrated system of organisms, ecosystems, and the biosphere. They further argue that the reductionist approach of treating life as a singular model, rather than as a system is partially responsible for the global environmental problems we face today. The book proposes six principles of holistic life science, including that it must be centered on the value of life, balance holistic and reductionist approaches, be able to model and understand complex life systems, and recommend actions for interacting with those systems.

To provide decision makers with clear indicators of resilience, IIASA researchers looked into novel network-based resilience concepts and measures from ecology that can also be applied to socioecological systems [2]. The concept of resilience actually already appears in the management principles of decision makers. A case study for the United States Bureau of Ocean Energy Management [3], for example, revealed how the bureau adopted a system that seeks to mimic and anticipate environmental change to manage for the resilience of marine ecological resources and their associated social elements. The study shows that a dynamic management framework that couples social and ecological systems can facilitate the efficient and effective utilization of resources, reduce uncertainty for decision makers, and lead to more defensible decisions on resources.

The network view on ecosystems was also innovatively used in a study aimed at understanding the use of eco-space and biodiversity [4]. The researchers looked at ecosystems in terms of the reactions that occur in response to changes in the system and then act as catalysts for other changes or interactions. They found that niche emergence, in other words, the ability of a species to evolve to adapt to their new circumstances, rather than niche partitioning where competing species use the environment differently to help them coexist, is what mostly drives ecological diversity.

Apart from engaging in research, IIASA scientists were also involved in the production of educational material for other scientists and the general public in 2018. This included editing the 2nd edition of the Encyclopedia of Ecology [5] and co-authoring several articles in Elsevier's Reference Module in Earth Systems and Environmental Sciences, an online database containing reference articles on major concepts and notions in particular scientific areas [6, 7, 8].

More information ar18.iiasa.ac.at/ecological-resilience

Air Quality and Greenhouse Gases

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
Publications
Staff
Scientific recognition

Selected highlights:

Informing clean air policies

Towards better air quality management in Vietnam

Improving the accuracy of national emissions inventories

Addressing the effects of climate change and air pollution

Informing clean air policies

Breathing clean air, the most basic human need, has become a luxury in many parts of the world. IIASA researchers contributed to a report representing the first comprehensive scientific assessment of the air pollution outlook for Asia and the Pacific.

Around 4 billion people living in the Asia-Pacific region – this is 92% of the population – are exposed to levels of air pollution that pose a significant risk to their health. Worldwide approximately 7 million people annually die prematurely from air pollution related diseases, with about 4 million of these deaths occurring in Asia-Pacific.

Researchers from IIASA led the modeling and quantitative analysis [1, 2] of the study that underpins the report and helped to identify simple and cost-effective measures that could deliver benefits across sectors. During their analysis the team realized that some measures have larger than expected potentials to reduce air pollution, while others generally thought to be effective make only a small difference. Knowing this could improve the effectiveness of policies. The work also considers the region's considerable diversity, showing that the identified measures are not equally appropriate for every part of Asia-Pacific, which means that they must be tailored, prioritized, and implemented according to national conditions.

The selected measures can be grouped into three categories. The first concerns conventional emission controls focusing on emissions that lead to the formation of fine particulate matter (PM2.5), in other words, particles such as dust, soot, and smoke that result from, for instance, the burning of fuel. Measures in this category includes activities like increased emissions standards and controls on vehicles, power plants, and large- and small-scale industry. The second category focuses on further air-quality measures aimed at reducing emissions that lead to the formation of PM2.5 and are not yet major components of clean air policies in many parts of the region. This includes actions like reducing the burning of agricultural and municipal solid waste, preventing forest and peatland fires, and proper management of livestock manure. Measures in the third category contribute to development priority goals with benefits for air quality. This includes using renewable energy for electricity generation, providing clean energy for households, improving public transport, and promoting the use of electric vehicles.

Millions of lives could be saved and one billion people living in Asia could be breathing clean air by 2030 if the simple and cost-effective measures outlined in the report are implemented. Specifically, effectively implementing the 25 measures would result in a 20% reduction in carbon dioxide and a 45% reduction in methane emissions, preventing up to a third of a degree in global warming. Resulting reductions in ground-level ozone could also reduce crop losses by 45% for maize, rice, soy, and wheat combined. According to the report, this will not only deliver substantial benefits to human health, food production, environmental protection, and climate change mitigation, but a basket of co-benefits that includes savings on pollution control will also accrue.

More information ar18.iiasa.ac.at/clean-air

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Improving the accuracy of national emissions inventories

Through chemical reactions in the atmosphere, ethane and propane affect the formation and loss of several air pollutants and greenhouse gases. A study involving IIASA researchers showed that global levels of these compounds have been grossly underestimated and that revision is needed.

Ethane and propane emissions are particularly harmful in large cities where, through chemical reactions with other emissions such as exhaust fumes from cars, they contribute to the formation of ozone – a greenhouse gas that is a key component of smog and directly linked to increases in mortality. The study [1] shows that global fossil fuel emissions of these compounds have been underestimated and could be more than 50% higher than previously thought. As most atmospheric ethane and propane comes from oil and gas activities, the underreporting of these hydrocarbons in national emission inventories can likely also be drawn back to these sources. According to the authors, it is vital that we understand the levels of hydrocarbons in the atmosphere to predict the exposure of populations to harmful emissions, which is particularly important for regions that are already at the upper limits of safe exposure.

The study employed an atmospheric transport model to compare how country-reported emissions inventories measured up to observed atmospheric concentrations of ethane and propane picked up at 27 monitoring stations around the Northern hemisphere. The results revealed that a substantial upward revision of emissions is needed. According to the researchers, major detailed atmospheric model studies performed to date have neglected natural geologic emissions of hydrocarbons, such as mud volcanoes, gas seeps, and volcanoes. In terms of man-made sources, this study is also the first to use two recently published fossil fuel (oil, natural gas, and coal) emission datasets. The first of these incorporates extensive country-level data on flows of associated petroleum gas (APG) to estimate considerably higher hydrocarbon emissions from APG venting than is currently assumed. The second inventory is based on a global bottom-up emissions inventory for ethane from the fossil fuel industry and a global database on source-specific isotopic compositions of gases released from various sources. Using these new fossil fuel emission datasets and adding the geologic emissions, the applied atmospheric model reproduces observed current ethane and propane levels in the Northern hemisphere, including episodic fluctuations.

The researchers caution that, although levels of ethane and propane declined in many places in the 1980s and 1990s, global growth in demand for natural gas means that these trends may be reversing. The resulting effects of higher ozone levels will be felt in the rural environment where it could damage crops and plants, as well as in cities where it will continue to have adverse effects on human health. This study is the first to offer possible explanations for what is missing from the existing emissions inventories, and could help to generate improved estimates. In addition, the results could aid in the development of strategies to reduce emissions.

More information ar18.iiasa.ac.at/accuracy-emissions

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Towards better air quality management in Vietnam

A collaborative research project between IIASA and the Vietnam Academy of Science and Technology has given rise to a multidisciplinary research community in Vietnam that can provide decision makers with comprehensive scientific support on air quality management.

A cooperative scientific project on air quality management in Vietnam between IIASA and its Vietnamese National Member Organization, the Vietnamese Academy of Science and Technology, reached an important milestone in 2018 with the publication of its first year's progress report. During the first year of the project, the IIASA Greenhouse Gas – Air Pollution Interactions and Synergies (GAINS) model was adapted to the Greater Ha Noi/Red River Delta area and surrounding regions, and an initial set of data compiled from publicly available statistics and studies. A report [1] on this phase of the project was presented at a workshop in Hanoi towards the end of 2018, which also marked the formal launch of the GAINS-Vietnam model.

The report highlights that air pollution is a real problem in Vietnam,

with the measured annual mean concentrations of fine particulate matter (PM2.5) in the air exceeding the global guidelines of the World Health Organization by a wide margin. PM2.5 refers to particles in the atmosphere that have a diameter of less than 2.5 micrometers – about 3% of the breadth of a human hair. These can come from various sources including power plants, residential wood burning, airplanes, motor vehicles, and forest fires. Because they are so small and light, these particles stay in the air longer, thus increasing the chances of humans and animals experiencing adverse health effects from inhaling them.

According to the researchers, Ha Noi's air quality could deteriorate even further in the future due to the anticipated increase in economic activity, despite the currently adopted policy measures. They caution that, without additional policy measures particulate matter concentrations in northern Vietnam could be 25-30% higher in 2030 than in 2015. This implies that almost 85% of the population in northern Vietnam would be exposed to air quality that does not conform to the national ambient air quality standard.

The analysis also shows that effective improvements of specifically Ha Noi's air quality will require coordination with neighboring provinces because, while about one third of PM2.5 exposure in Ha Noi originates from emission sources within the same province, the majority is imported from outside. This means that if restricted to the Ha Noi province, even the most stringent emission control measures will be insufficient to effectively reduce ambient pollution levels in the city.

Although further work will be necessary to refine the GAINS-Vietnam tool, the initial findings are highly relevant for air quality management in the country. Cost-effective strategies need to combine technical emission controls with policies that promote structural changes, such as energy efficiency improvements and a transition to cleaner fuels. Once fully implemented, the GAINS-Vietnam tool could help to identify effective portfolios of measures that take into account the costs, benefits, and political economy of policy interventions.

More information ar18.iiasa.ac.at/air-vietnam

Addressing the effects of climate change and air pollution

IIASA researchers contributed to a major new report looking at the effects of climate change on human health and its implications for society. The authors examined indicators across a range of themes, and urge action to safeguard populations against negative impacts.

The summer of 2018 made headlines as one of the hottest on record and research focusing on northern Europe showed that the heat waves experienced across the region were twice as likely to have happened due to man-made climate change. The report [1] published by the research coalition The Lancet Countdown, highlights that rising temperatures as a result of climate change are exposing especially vulnerable populations to unacceptably high health risks. The authors warn that it could also have dire effects for our existing health systems and economies, which are currently ill equipped to deal with the effects of rapidly increasing temperatures

The report further discusses the finding that air pollution resulted in several million premature deaths globally from ambient fine particulate matter in 2015 – a conclusion that confirms earlier assessments from IIASA researchers. Since air pollution and greenhouse gases often share common sources, the report advocates that mitigating climate change constitutes a major opportunity for direct human health benefits.

An important finding around the dangers of air pollution to human health contributed by IIASA researchers using the Greenhouse Gas – Air Pollution Interactions and Synergies (GAINS) model, for instance, demonstrated that coal alone accounts for 16% of global pollution-related premature deaths, around 460,000. They explain that this makes phasing out coal-use a "crucial no-regret intervention for public health". The researchers however point out that although coal should be a key target for early phase-out in households and electricity generation as it is highly polluting, it is not all that should be done, as air pollution is a multi-faceted issue that requires integrated strategies cutting across many sectors, which will also differ from country to country.

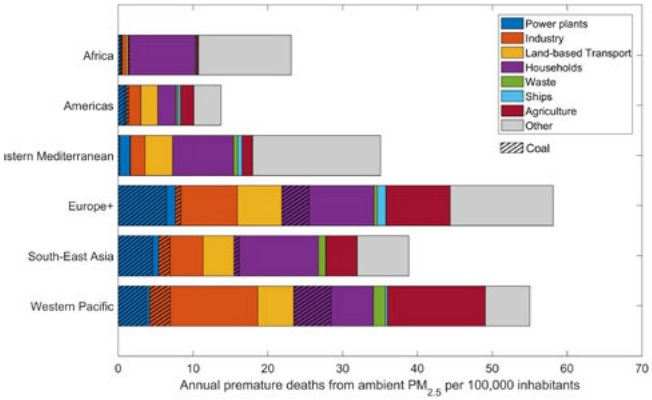

Figure 1: Health impacts of exposure to ambient fine particulate matter (PM2.5) in 2015, by key sources of pollution. Coal as a fuel is highlighted by hatching.

The report, examined 41 separate indicators across a range of themes, and calls for urgent steps to protect people from the impacts of climate change. In particular, the authors suggest that stronger labor regulations are needed to protect workers from extremes of heat, and that hospitals and the health systems we rely on need to be better equipped to deal with more extreme climate conditions. There are however limits to adapting to temperature increases, and if left unabated, climate change and heat will overwhelm even the strongest of systems, which means that the need for reducing greenhouse gas emissions is critical.

Other findings contained in the report include a new indicator mapping extremes of precipitation that identifies the regions most exposed to flood and drought. In terms of food security, the report points to 30 countries experiencing downward trends in crop yields, reversing a decade-long trend that had previously seen global improvement. Yield potential is estimated to be declining in every region as extremes of weather become more frequent and more extreme.

More information ar18.iiasa.ac.at/climate-change

Ecosystems Services and Management

Program website
Publications
Staff
Scientific recognition

The Ecosystem Services and Management Program (ESM) has built integrated knowledge and data systems to provide a trusted science base for land management policy processes in many global regions. These aim to improve human wellbeing and sustainable management of the Earth's natural resources. Guiding production and consumption choices that are consistent across scales and compatible with the maintenance of equitable access to multiple ecosystem services, is a scientific challenge that ESM is uniquely positioned to address based on its cluster of citizen science and modularly linked land resource assessment tools.

Selected highlights:

Coal jobs vs. climate change mitigation

Thinking small to ensure global food security

Thawing permafrost and our warming planet

A call for climate-smart agricultural policies

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Coal jobs vs. climate change mitigation

Contrary to how it is often portrayed in the public discourse, IIASA-led research has found that the goals of coal sector employment and climate change mitigation can actually be aligned.

As the need for solutions to the impending consequences of rising global temperatures has become increasingly urgent, concerns have been raised about the loss of jobs if current technologies like coal-fired power plants are phased out. In a 2018 IIASA-led study, researchers modeled the transformation of the US coal sector until 2050. According to the results, the most optimal strategy for meeting the 2050 emission reduction targets consistent with staying below 2°C warming, is through the early deployment of bioenergy with carbon capture and storage (BECCS) and by replacing 50% of aging coal plants with natural gas plants. This would not only retain the current 40,000 jobs in the US coal industry, but would also create 22,000 new jobs in related sectors by the middle of this century.

Carbon dioxide removal (CDR) technologies that aim to remove and sequester excess carbon from the atmosphere, have been identified as an important part of the response to climate change. Among them, BECCS combines carbon capture and storage, in which CO_2 is collected from large emission sources such as power plants and injected into underground geologic formations, with the use of plant-based materials (biomass) as a source of fuel. The future role of BECCS and the scale of its deployment are still controversial, but the results of this study show that acting now and investing in this emission-mitigating strategy can be beneficial for employment in the sector.

The researchers studied the major processes and steps involved in the potential energy supply chains for the US coal fleet. Specifically, they looked at the supply of biomass resources from managed and certified US forests and the design and cost of infrastructure for transporting and injecting CO_2 into appropriate geological sites, taking into account that biomass must be grown and harvested in a sustainable way to be considered carbon-neutral and thus lead to negative emissions.

The team used a number of different models to analyze existing data, including two from IIASA, the Global Forest Model (G4M), which looks at income from forestry and alternative land uses, and the BeWhere model, which optimizes the technology development of US coal power plants, including feedstock logistics. They also used the Jobs and Economic Development Impact model (JEDI) from the National Renewable Energy Laboratory (NREL), to estimate the employment impacts of technology development.

According to the researchers, repurposing US coal plants presents a rare opportunity to address both emission mitigation and job creation if the right technology change is adopted. They propose that, rather than arguing that climate change mitigation is simply necessary, policymakers should inform the coal sector that such strategies entail employment opportunities.

More information ar18.iiasa.ac.at/coal-climate-change

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Thawing permafrost and our warming planet

The results of a study by IIASA researchers shows that carbon release from rapidly thawing permafrost is adding to global warming, and that the world could be closer to exceeding the long-term target of the Paris Agreement than previously thought.

The study is the first to comprehensively account for permafrost carbon release when estimating emission budgets for climate targets, and specifically looked at how current emission budgets are impacted by CO_2 and methane emissions from thawing permafrost.

An emissions budget is the maximum allowable amount of total CO_2 emissions to stay below a specific global average temperature. Because it is such a simple concept, it has become a popular tool for policymakers in efforts to remain below dangerous levels of warming. Emissions budgets, however, have a shortcoming in that they are strongly dependent on an assumed linear relationship between global temperature rise and cumulative CO_2 emissions due to human activity.

Permafrost is soil that has been frozen year round for at least two years. Large amounts of carbon and other nutrients from organic matter is stored in the frozen soil, and is seldom considered in projections of potential future global warming. Although it is normal for the upper layer of permafrost to periodically thaw during the summer months, in recent years, this layer has gradually been expanding due to increasing temperatures. This means that more permafrost is thawing and releasing the previously trapped carbon into the atmosphere, which will reduce the budget of CO_2 we can emit while staying below 2°C of global warming. It is also an irreversible process over the course of centuries, and may be considered a "tipping" element of the Earth's carbon-climate system that puts the emission budget framework to the test.

By adequately accounting for such a tipping process in emission budgets, the results of this study show that the world is much closer to exceeding the budget for the long-term target of the Paris Agreement than previously thought. The results further indicate that the effect can become even more significant for overshooting trajectories, in other words, first exceeding the targeted level, and then going back down to the target. The Paris Agreement explicitly acknowledges an overshooting trajectory, peaking first at 'well-below' 2°C and then pursuing efforts to get back to 1.5°C. During the overshoot period however, rising temperatures will lead to further permafrost thaw, which will in turn lead to more released carbon that will have to be removed from the atmosphere for global temperatures to decrease.

The researchers caution that this is a risky strategy and getting back to lower levels after an overshoot will be extremely difficult. We might even have to prepare ourselves for the possibility of never getting back to safer levels of warming. They hope that their work will impact the scientific community by demonstrating that emission budgets are not as simple a tool as first thought and that it will help policymakers to design effective future climate mitigation strategies.

More information ar18.iiasa.ac.at/permafrost

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Thinking small to ensure global food security

A global data set of agricultural field sizes collected as part of a crowdsourcing project by IIASA researchers, has shed new light on the contribution that smallholder farms make to world food production.

Evidence is mounting that smallholder farms, in other words, agricultural fields of less than around two hectares (ha) in size, make a substantial contribution to world food production. In addition, field size is known to be a good indicator of agricultural intensity, which could provide policymakers with valuable information around food security issues. Previous estimates of the total land area used for agriculture have suggested that smaller plots make up between 12% and 24% of the global total. A study led by IIASA researchers, however, puts the total land area of smallholder farms at 40% and has helped to fill some of the gaps in available information on global agricultural field size distribution.

The crowdsourcing campaign that provided the data for the study ran for four weeks starting in June 2017. Data was collected using the Geo-Wiki app, which takes high-resolution satellite imagery from Google Maps and Microsoft Bing and allows users to visually assess those images. In this case, users were asked to assess images of agricultural land.

A field was defined as any enclosed agricultural area, including arable and pastureland that could be separated by roads, permanent paths, or vegetation. Users could choose one of five field size categories – very large (greater than 100 ha), large (16-100 ha), medium (2.56-16 ha), small (0.64-2.56 ha), and very small (less than 0.64 ha). An instructional video and slides were used to train participants on how to use the app. Before being allowed to contribute to the official survey, users were asked to complete ten training images, with feedback given on each. Random 'control' images that had been expertly assessed were also randomly shown to users, and if these were incorrectly classified,

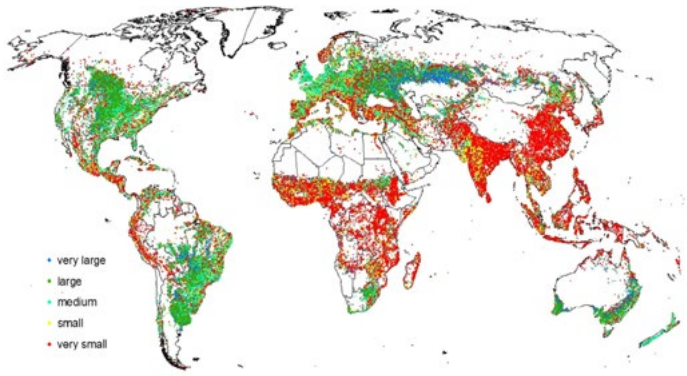

Figure 1: Global distribution of field sizes [1].

the user received text feedback. This quality control feature was introduced to improve the quality of the results. Prizes were offered as an incentive to participate.

Each image was assessed by three users. A total of 130,000 unique samples were collected over the course of the four weeks, and the researchers used the 390,000 classifications (from three 'visits' to each site) to create a map and calculate the agricultural area proportions at the global, continental, and national levels. The study is the first to estimate field sizes at all three levels, and on a global scale. The resulting data set is much more detailed and denser than anything previously collected and is openly available for use in future research.

According to the researchers, this information will give policymakers an accurate overview of the global distribution of field sizes, thus providing better background knowledge for decision making related to food systems and agriculture, and ultimately supporting better policy decisions related to food security issues.

More information ar18.iiasa.ac.at/food-security

A call for climate-smart agricultural policies

The world will have to sustainably feed 10 billion people by 2050, but the ways in which we are currently producing and consuming food is putting pressure on the environment. Several IIASA studies looked into these issues in 2018.

The agricultural sector is the world's largest source of non-CO_2 greenhouse gas emissions. In fact, emissions from agriculture currently make up 10-12% of anthropogenic greenhouse gas emissions and the percentage is growing, largely thanks to the increased use of synthetic fertilizers and growing ruminant herds. If the world is to meet the 1.5°C climate stabilization target set out in the Paris Agreement, these emissions will have to be reduced.

IIASA researchers were part of a team that analyzed agricultural non-CO_2 mitigation using a combination of four global economic models and assessed the reduction potential [1]. They estimated the potential of a comprehensive set of options on both the supply and demand side across regions and gained insights into the contribution and importance of different areas of mitigation.

The beef and dairy industries in particular are highly greenhouse gas intensive, and across all models and carbon price scenarios, had the ability to contribute more than two thirds of the total mitigation potential in agriculture. The study identified three areas for mitigation on the supply side including technical options, such as animal feed supplements; structural options, such as changes in crop and livestock portfolios; and production effects, such as changes in production levels. Demand side options involved consumers in developed and emerging countries switching to diets with fewer animal products. The results show that steering mitigation action towards a limited number of regions and commodities such as beef and milk would allow for substantial emissions savings, even at low costs. Implementing all options together could reduce the sector's emissions by up to 50% by 2050 compared to a situation without such efforts.

Another study [2] similarly showed that the economic potential of non-CO_2 emissions reductions from agriculture could be up to four times as high as previously estimated if all mitigation areas on the supply side are considered. The researchers urge immediate action to favor the widespread adoption of technical options in developed countries, along with productivity increases through structural changes in developing countries, to move the agricultural sector towards a climate stabilization pathway.

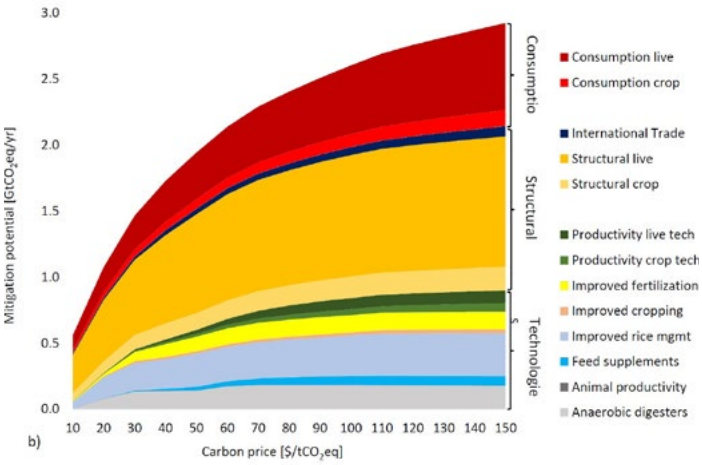

Figure 1: Global economic non-CO_2 mitigation potential in agriculture by 2050 at increasing carbon price levels.

Work with researchers from Japan further revealed that a single climate mitigation scheme applied to all sectors, such as a global carbon tax that also includes agricultural emissions, could have a serious impact on agriculture and result in far more widespread hunger and food insecurity than the direct impacts of climate change [3]. The findings indicate that without careful planning, the burden of current mitigation policies is simply too great. The researchers however emphasize the importance of "smart", targeted policy design, particularly in agriculture, and advise policymakers to scrutinize other factors and development goals more closely, rather than focusing only on the goal of reducing emissions when designing climate mitigation policies for the agricultural sector.

More information ar18.iiasa.ac.at/agricultural-policies

Energy

The way society uses energy gives rise to major environmental, social, and economic challenges. The Energy Program identifies viable solutions to these challenges, analyzes whether current policies are on track, and employs a systems perspective to examine interactions between different sectors and objectives. A central focus of the research is on energy strategies that help maximize synergies and minimize trade-offs between different societal objectives.

Program website
Publications
Staff
Scientific recognition

Selected highlights:

The finance risks and opportunities of decarbonization

National energy modeling and capacity development

Contributing to science based climate targets

Translating energy and climate research into policy

The finance risks and opportunities of decarbonization

If financial markets become more long-term oriented, they could potentially become a catalyst for action on sustainability. In 2018, IIASA scientists collaborated with international banks and researchers from other institutions to assess the financial implications of deep decarbonization strategies.

Researchers from the institute collaborated with a consortium of 16 leading banks from four continents convened by the UN Environment Program Finance Initiative (UNEP FI) to publish a jointly developed methodology to increase banks' understanding of how climate change and climate action could impact their business. This understanding is fundamental to enabling banks to be more transparent about their exposure to climate-related risks and opportunities in line with the Task Force on Climate related Financial Disclosures (TCFD). It will also inform banks' strategies to contribute to and benefit from low-carbon economic transition, and help them engage and support their customers to that effect. This is important because the climate-related risks and opportunities that banks face arise primarily from their services to clients.

The IIASA team contributed to the methodology development and provided detailed scenario data from the MESSAGEix-GLOBIOM integrated assessment model, which formed the basis of the report, together with the Potsdam Institute for Climate Impact Research's REMIND-MAgPIE model. The team developed risk factor pathways for individual economic sectors in different world regions. Three scenarios were used in the project: a baseline, and deep decarbonization pathways consistent with 2°C and 1.5°C warming. These scenarios were developed within the context of the ongoing European Commission Horizon 2020 research project CD-LINKS, which is coordinated by IIASA.

In another project, IIASA scientists led an international consortium that analyzed the required investments for meeting the targets of the Paris Agreement. The study [1] found that a fundamental transformation of the global energy system can be achieved with a comparatively modest increase in overall investments. However, a radical shift of investments away from fossil fuels and toward renewables and energy efficiency is needed (Figure 1) along with dedicated investments into measures to achieve the UN Sustainable Development Goals (SDGs).

To keep global temperature rise to 1.5°C or 2°C, investments in low carbon energy and energy efficiency will likely need to overtake investments in fossil fuels as early as 2025 and then grow far higher. The low carbon and energy efficiency "investment gaps" calculated by the researchers are striking. To meet countries' nationally determined contributions (NDCs), an additional US$130 billion of investment will be needed by 2030, while to achieve the 2°C target the gap is $320 billion, and for 1.5°C, it is $480 billion. These investment figures represent more than a quarter of total energy investments foreseen in the baseline scenario, and up to half in some economies such as China and India.

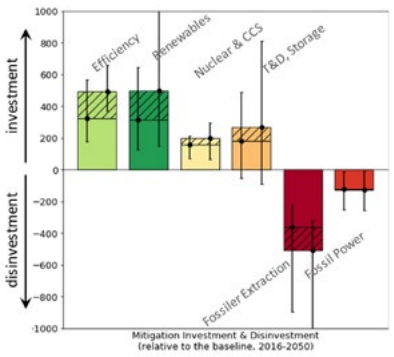

Figure 1: Mitigation Investments and Disinvestments of reaching the climate objective of 2°C and 1.5°C temperature change. Cross-hatched areas indicate additional investment or disinvestment of 1.5°C compared to 2°C. [1].

In addition to the above efforts, IIASA scientists also participated in the Scientific Advisory Group of the Science Based Targets initiative, contributed to the Integrated Assessment Modeling Consortium (IAMC) Working Group on Climate Finance, and participated in several workshops with the financial sector.

More information ar18.iiasa.ac.at/decarbonization

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Contributing to science based climate targets

IIASA researchers contributed significantly to the 2018 Intergovernmental Panel on Climate Change (IPCC) Special Report on Global Warming of 1.5°C (SR1.5). Researchers from the institute also developed a new scenario explorer on behalf of the IPCC Working Group III and the scientific community.

The SR1.5 report highlights the strong benefits to humanity and ecosystems of keeping global warming to 1.5°C rather than 2°C above pre-industrial levels. IIASA researchers were intimately involved in the writing of the report, including in the capacity of coordinating lead author of Chapter 2 on mitigation pathways, and taking the lead on the analysis of sustainable development implications of mitigation summarized in Chapter 5. In addition, they were responsible for the compilation of a scenario repository underpinning important findings of the report, and were also contributing authors to various other chapters.

IIASA research critically underpins a wide range of findings of the IPCC report, from impacts and vulnerability to mitigation. One IIASA study [1] was specifically instrumental in illustrating the large difference between 2°C and 1.5°C in terms of exposure to multi-sectoral hotspots in Chapter 3 of the report (Figure 1). In addition, a dedicated study with a focus on mitigation [2] guided the report's findings on the feasibility of reaching the 1.5°C target. The IIASA-led international CD-LINKS consortium contributed 36 scenarios to the IPCC assessment, while MESSAGE-GLOBIOM scenarios were used to illustrate the challenges in specific sectors and sources where greenhouse gas reductions are most difficult to achieve. In sum, two out of four illustrative pathways featured by the IPCC SR1.5 – the Shared Socioeconomic Pathway 2 (SSP2) and the Low Energy Demand (LED) scenario [3] – were from IIASA, where they were jointly developed by a number of the institute's research programs.

These scenarios along with many others developed by the worldwide climate research community are part of a unique data set that underpins the IPCC report. IIASA hosts these scenarios for the community in a publicly accessible repository – the so-called Integrated Assessment Modeling Consortium (IAMC) 1.5°C Scenario Explorer [4].

The scenario explorer provides a critical service to the policy and scientific community. It includes 414 scenarios for future climate change developed by more than a dozen research teams from around the world. These scenarios provide information related to the energy system, greenhouse gas emissions, land use change, and other factors connected with climate change and sustainable development. It also includes visualization tools for exploring the data, so that policymakers and researchers in related fields like climate finance can explore different options for climate action and their potential consequences.

The aim of the new scenario explorer is to help increase the transparency of IPCC assessments, and facilitate better understanding of synergies and trade-offs of climate change mitigation options with sustainable development.

More information ar18.iiasa.ac.at/climate-targets

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National energy modeling and capacity development

In 2018, IIASA researchers organized several capacity development activities. These comprised workshops on best practices in energy and integrated assessment modeling as well as hosting researchers from IIASA member countries to jointly develop and apply methods to address energy-related challenges.

As part of the CD-LINKS project, IIASA and The Energy and Resources Institute (TERI) co-organized a workshop on integrated assessment modeling and data analysis and visualization tools in New Delhi, India. A series of events on integrated solutions for the water-energy-land nexus, including a contribution to the Third Indus Basin Knowledge Forum, were co-organized by IIASA researchers in India, Pakistan, and at the institute's premises in Austria. Similar workshops are planned to be held in Brazil and Israel, while a summer school on integrated assessment modeling in Venice, Italy will be co-organized by IIASA in 2019.

IIASA researchers are developing sustainable energy pathways under the umbrella of the UN Economic Commission for Europe (UNECE) in close cooperation with national stakeholders from Russia, Ukraine, and several central Asian states. First results indicate the significant benefits for all in case of improved collaboration within the region (Figure 1). The analysis was presented at a conference in Kiev, Ukraine

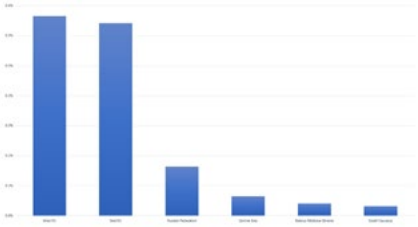


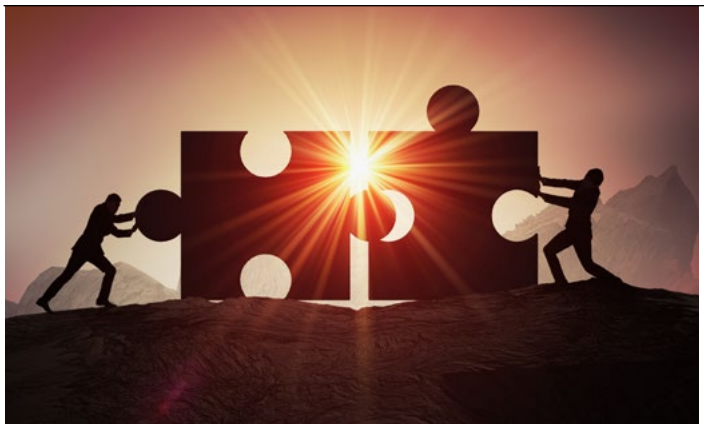
Figure 1: Comprehensive economic gains from establishing a regional carbon market in Eurasia. All actors benefit when reaching their national targets. Y-axis depicts gains expressed in percent per GDP. Source: Behnam Zakeri, project hosted by the United Nations Economic Commission for Europe (UNECE).

in November 2018. As part of this effort, a methodology for the rapid prototyping of country-scale energy models was developed. The plan is to apply the tool more widely, including to other IIASA member countries.

Another prominent example of national modeling is the institute's successful collaboration with the National Institution for Transforming India (NITI Aayog), which launched its national energy systems model in 2018. The NITI model was co-developed with IIASA support, and is based on the open source MESSAGEix modeling platform. As part of the model development, training was provided for young professionals in India to ensure that modeling and analytical capacity in Indian institutions are strengthened.

Over the course of 2018, the IIASA Energy Program hosted seven early and mid-career researchers from IIASA member- and observer countries, including Brazil, China, Iran, Israel, and Pakistan for extended periods to jointly work on research projects. These research exchanges on the one hand help to bring methods and best practices in modeling to IIASA member countries, and on the other, improve the in-depth knowledge of challenges faced by individual countries and their representation in analytical tools within the program.

More information ar18.iiasa.ac.at/energy-modeling



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Translating energy and climate research into policy

Part of the IIASA mission is to provide scientific guidance to policymakers. In 2018, IIASA scientists continued to engage in international and national policy processes by translating cutting-edge science into policy relevant insights for energy and climate policymakers and negotiators.

IIASA researchers authored four policy briefs that were submitted as inputs to the UN Talanoa Dialogue Platform. These covered a range of insights on "Opportunities for enhanced action to keep Paris goals in reach"; "Why are nationally determined contributions (NDC) projections so uncertain and how can they be made more precise?"; "What investments are needed in the global energy system in order to satisfy the NDCs and 2°C and 1.5°C goals?" [1]; and "Learning from the past: How energy and climate policies can foster the broader sustainable development agenda?" An additional IIASA policy brief further highlighted the substantial benefits of climate mitigation and achieving the 1.5°C target, as well as where action is most urgently required to reduce the vulnerability of the world's poorest to unavoidable climate impacts.

In November 2018, at an event hosted by the Global Climate Forum, three EU Horizon 2020 funded projects CD-LINKS, GREEN-WIN, and TRANSRISK participated in a joint policy day in Brussels, Belgium. The event integrated complementary perspectives on climate goals by collectively presenting the core findings of the three EU-funded projects together with their implications for climate policy. IIASA scientists presented results from the CD-LINKS project that explore the complex interplay between climate action and development, while simultaneously taking both global and national perspectives into account to inform the design of complementary climate-development policies.

IIASA researchers also cohosted and participated in several side events at the 2018 UN Climate Change Conference (COP24). At a side-event co-organized with the New Energy and Industrial Technology Development Organization (NEDO) of Japan and the UK's Carbon Trust, IIASA researchers presented the Integrated Assessment Modeling Consortium (IAMC) 1.5°C Scenario Explorer – an interactive tool for full access to the scenarios of the Intergovernmental Panel on Climate Change (IPCC) Special Report on Global Warming of 1.5°C. The Scenario Explorer, which was developed by IIASA on behalf of the IAMC and IPCC Working Group III, is equipped with an interactive interface that allows policymakers and researchers in related fields such as climate finance easy access and analyses of the pathways.

The team spearheading the CD-LINKS workshop as part of the United Nations Framework Convention on Climate Change Capacity-building Hub at COP24 in Katovice, Poland (from left to right): Daniel Huppmann, IIASA; Swapnil Shekar, Indian Institute of Management Ahmedabad (IIAM), India; Heleen van Soest, PBL Netherlands Environmental Assessment Agency; and Volker Krey, IIASA.

At an event hosted by the Paris Committee on Capacity-building (PCCB) at COP24, IIASA scientists presented a number of capacity building and knowledge sharing activities related to CD-LINKS. These included tools for assessing the impact of climate policies and NDCs, as well as the MESSAGEix modeling framework and other state-of-the-art tools for integrated scenario analysis.

Finally, at another COP24 side event in collaboration with the COMMIT project and the German Umweltbundesamt, IIASA researchers showcased results from the CD-LINKS project on integrated global and national low-carbon transformation pathways, their link to sustainable development objectives, as well as the experience of major economies in different areas of implementation and policy design.

More information ar18.iiasa.ac.at/energy-climate-policy

Evolution and Ecology

The Evolution and Ecology Program analyzes and forecasts how ecological and evolutionary dynamics shape populations, communities, and ecosystems in order to build bridges between the different dimensions that comprise the analysis of living systems. The innovative methods developed by the program's researchers are inspired by the dynamics of living systems and integrate key facets of modern applied systems analysis.

Program website
Publications
Staff
Scientific recognition

Selected highlights:

Facilitating the sustainable use of common resources

Improving descriptions of biodiversity dynamics

Policy advice informed by evolutionary fisheries science

Analyzing potential shocks to financial systems

Facilitating the sustainable use of common resources

Ensuring the sustainable use and preservation of common resources is one of the major challenges facing humanity over the next century. Three studies undertaken by IIASA researchers in 2018 looked into conditions that would make this possible.

Common goods such as climate, clean air, natural forests, or fish stocks, can be threatened by over-exploitation. In an influential 1961 publication, the American ecologist and philosopher Garrett Hardin called attention to the damage that seemingly innocent actions by individuals can inflict on the environment by adhering to individually rational decisions, that when aggregated may have disastrous consequences at the population scale. This phenomenon, which Hardin dubbed "the tragedy of the commons", is often studied using a game-theoretic model known as a public goods game. In the simplest instance, the public goods game permits only selfish exploitation as the long-term outcome.

Much effort has been put into research aiming to clarify the factors that facilitate sustainable resource use. IIASA researchers specifically investigated how cultural values and the entanglement of common resources and public welfare influence individual decisions, and how information availability and different interactions can help facilitate the sustainable use of common resources.

The vast majority of research on the public goods game have considered only a single resource in isolation. Realizing that several important public goods such as clean air, lush forests, and social security, affects individuals in more than one way, IIASA researchers increased the realism of the public goods game by assuming that the common resource directly affects public welfare [1]. In a large experiment, they asked 320 participants to play a computer game in which the public good was represented by a forest that could be harvested for revenue, but that simultaneously could be protected against recurrent floods. They found that flood risk helped to reduce overexploitation and that egalitarian values among the participants improved the group's ability to preserve the forest.

One of the studies aimed at shedding light on the role of different types of interactions and information availability for ensuring sustainable resource usage, corroborated the traditional understanding that a higher likelihood to interact with individuals of the same type promotes cooperation [2]. The other study paradoxically found conditions under which a higher likelihood of interacting with individuals of another type tends to promote cooperation, and revealed that information on the actions taken by the other individuals can sometimes be detrimental to cooperation [3]. These studies show the need to consider many facets simultaneously in order to understand the factors and conditions that facilitate sustainable resource use.

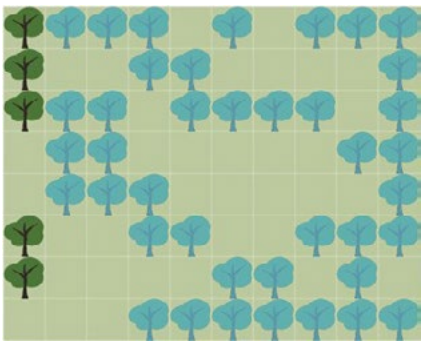

Figure 1: An illustration of the forest game from [1]

More information ar18.iiasa.ac.at/common-resources

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Policy advice informed by evolutionary fisheries science

Fishing not only affects the numbers of fish, but also their heritable characteristics through evolutionary changes. IIASA research in this area sheds light on how fish reproduce under increasing fishing pressure, which has important implications for the regulation of fisheries.

Fish populations live in an ever-changing interaction with their environment. One key aspect of this interaction is so-called compensatory mechanisms. These are processes that make populations more productive when they decline, thus facilitating their recovery, and less productive when they approach the carrying capacity of their environment, which eventually prevents further population growth.

In fisheries science, it has traditionally been assumed that the main compensatory mechanism occurs through recruitment, which is the process whereby the population grows due to the addition of juvenile fish. The compensatory mechanism takes effect when the population gets larger, causing each spawning fish to produce on average fewer surviving offspring. This assumption underlies much of the scientific advice that helps fishery managers establish sustainable fishing levels.

At the same time, there is little empirical evidence of such a relationship between the abundance of spawning fish and the resulting recruitment. How can we reconcile these apparently conflicting suppositions?

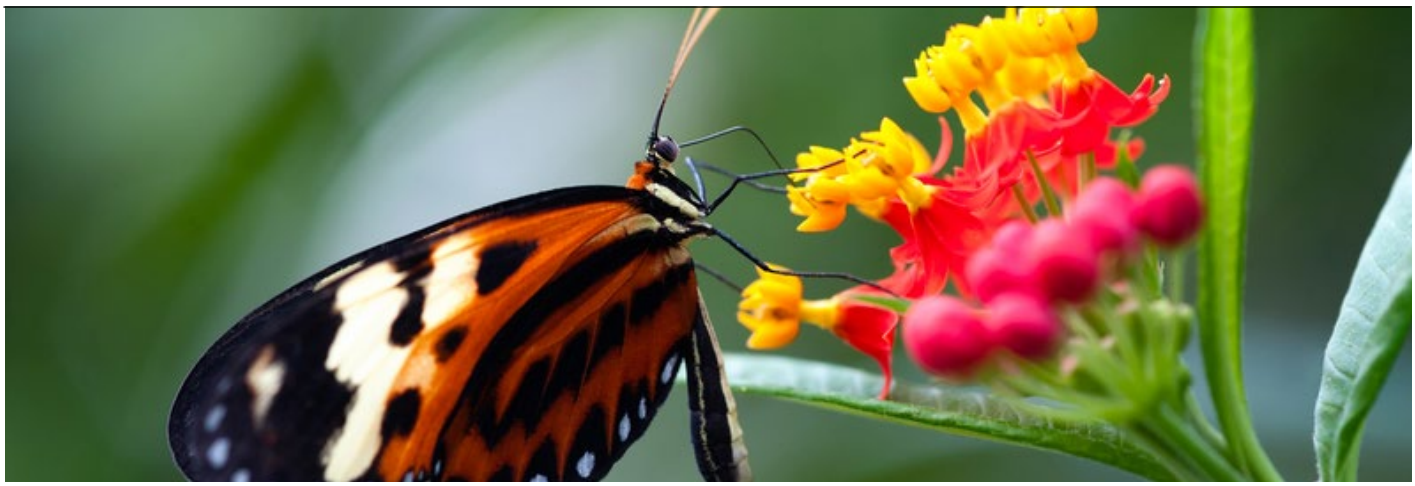
One possibility is that other compensatory mechanisms than recruitment are important. A plausible mechanism is that fish grow slower in relatively crowded populations. IIASA researchers tested this hypothesis with data from a large number of fish populations from the Northeast Atlantic [1]. Long time series data of population size, recruitment, and average body weights allowed the team to compare the strength of compensation between population size and recruitment, as well as between population size and body growth.

The results show that the old wisdom of compensation in recruitment holds water. In most cases, compensation in recruitment was stronger than compensation in growth. However, compensation in growth was often present too, and in a few cases, it was a stronger compensatory mechanism. This is an important insight because ignoring compensation in growth when it is actually present, may lead to management advice that predicts overly positive outcomes for fish stock rebuilding plans [1].

Observations of individual fish can reveal more subtle changes in population characteristics occurring over longer time scales. Probabilistic maturation reaction norms, which is a method previously developed and applied at IIASA [2], have typically suggested that marine fish populations evolve a tendency to start reproduction at an earlier age in intensively exploited populations [3].

A study undertaken at Lake Erie in the US, however, shows the opposite pattern. Following a reduction in the exploitation pressure, yellow perch females started to delay their reproduction. This is a rare example of a possible evolutionary recovery towards a more pristine reproductive schedule [4]. A comparison over space rather than time of two populations of cutlass fish (a major commercial species in East Asia) further revealed that the population exposed to higher fishing pressure matured earlier than the one facing less pressure from fishing [5].

More information ar18.iiasa.ac.at/fisheries



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Improving descriptions of biodiversity dynamics

Eco-evolutionary models are becoming increasingly important for biodiversity management as they enhance the realism of how underlying processes are represented. IIASA researchers contributed towards improving descriptions of biodiversity dynamics by using newly available data and incorporating evolutionary processes into ecological models.

The management of living systems is often difficult due to the presence of several structuring processes that can create unexpected feedbacks and dependencies. As a case in point, models used in fisheries management have traditionally been based exclusively on ecological processes, but in the late 1990s, IIASA researchers realized that evolutionary processes might also be important. They later demonstrated that the inclusion of evolutionary processes in these models could greatly improve policy recommendations. Determining which of these processes are important in any given ecological system is however difficult, as most of the relevant processes can rarely be directly observed in the field.

One study by IIASA researchers [1] demonstrated how underlying eco-evolutionary processes can be assessed by drawing upon and

synthesizing several sources of data such as trait- and species distributions, abundances, and the evolutionary development and diversification of species or groups of organisms. The proposed methodology builds on characterizing species in terms of functional traits and describing the underlying structural processes in terms of mathematical equations for rates of change. A recently developed statistical technique known as Approximate Bayesian Computation (ABC) was applied to infer the relative importance of processes.

Two other studies improved the representation of individual life cycles [2] and showed how to account for environmental changes associated with latitude in forest models [3]. In a further study [4] researchers also considered the problem of statistically validating model outcomes that span large spatial regions, particularly for global vegetation models that can make predictions at any point across the globe. The technique incorporates small-scale variability and observational errors to improve comparisons of large-scale area averages with small-scale point estimates.

Using a new large dataset of 257 subtropical and tropical islands, IIASA research [5] showed how the risk of invasion by alien species on islands increases with the island's remoteness. According to the researchers, islands are hotspots of alien species invasions, and their distinct biodiversity is particularly vulnerable to these invaders. The paper highlights that globalization in trade and transport has led to a breakdown of biogeographical barriers and the subsequent colonization of islands by foreign species, which has important implications for ecosystem sustainability.

More information ar18.iiasa.ac.at/biodiversity-dynamics

Analyzing potential shocks to financial systems

Understanding the dynamics of an emerging economy like Mexico requires insight into the shocks that could impact its external financial account and particularly its stock market. IIASA researchers analyzed interactions between risk and financial interrelations to provide policy recommendations aimed at lessening or avoiding risk.

Economic and financial interrelations in especially developing economies are complex and require innovative models to analyze external and internal shocks. In their study [1], IIASA researchers set out to determine the main shocks that affect the capital flow dynamics in Mexico. They also modeled the country's complex economic system using a system-dynamics methodology focusing on the stock market [2].

In an emerging market economy (EME) like Mexico, the current account may be vulnerable to external shocks and reversals of capital flows. It is therefore fundamental to determine external factors such as global risk, liquidity, economic activity, and the foreign interest rate, as well as internal factors like domestic economic activity, inflation, the domestic interest rate, and the exchange rate, that affect the financial account. A country's financial account comprises foreign direct investment (FDI), as well as portfolio and other investments, where FDI could be a catalyst for economic growth. For that reason, it is important to understand the push and pull factors that determine the capital flows and to avoid or reduce external shocks.

The researchers explain that under highly uncertain conditions, external shocks raise risk because the push factors are beyond the control of EMEs, although they can be mitigated. In the capital flow recipient country, risk can be exacerbated if there are account deficits, inflationary pressures, and appreciation of real exchange rates. This could in turn induce systemic failures. To avoid damage to the economy or the possibility of a financial crisis spreading to EMEs as a result of external financial and economic turbulence like during the financial crisis of 2008, it is essential to improve the pull factors or the prevailing economic conditions in each country, and for EMEs to have economic policies that mitigate external shocks.

The researchers found that global liquidity, the federal funds rate, and global risk are the main determinants of portfolio investment by foreign investors. The results further revealed that in Mexico, an increase in global risk leads to lower portfolio investment in private sector securities and higher portfolio investment in public sector securities, as these are less risky.

The Mexican financial account and stock market provide a wealth of information about the network dynamics of both the external and financial sector. To this effect, IIASA researchers also used a macroeconomic equilibrium model to show the importance of the stock market in the economic growth of an EME.

These studies highlighted the importance of understanding how external and internal shocks affect capital flows to Mexico and the stock market. Based on their results, the researchers provided economic policy recommendations that could reduce risk and contribute to developing a healthy external and financial sector in Mexico as well as in other EMEs.

More information ar18.iiasa.ac.at/financial-systems

Risk and Resilience

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
Publications
Staff
Scientific recognition

Selected highlights:

Mainstreaming extreme risk into fiscal and budgetary planning

Supporting the policy discourse around Loss and Damage

Breaking out of technological lock-in

Serious gaming for risk communication and engagement

Mainstreaming extreme risk into fiscal and budgetary planning

Climate change is having a visible impact on biological, physical, and human systems and this trend will likely continue into the future. Longer-term fiscal assessments will be crucial for public authorities to be adequately prepared for increasing climate-related risks.

Studies show that 43% of all recorded climate-related and geophysical disasters between 1998 and 2017 were floods, representing 23% (or US$656 billion) of related economic losses. Austria, in particular, has been subject to recurrent large-scale flooding leading to losses of several billion Euros in 2002, 2005, and 2013. Although Austria has a disaster fund in place to deal with impacts and implement preventive building measures, the fund's setup is not based on longer-term planning procedures.

The country is however not alone in employing a static approach to public disaster risk financing. While aging-related costs are often perceived as major drivers of fiscal pressure, concerns over climate-related public expenditure have received comparatively little attention. Longer-term drivers of extreme climate risks include changes in hazard frequency and intensity due to climate change, as well as socioeconomic trends like urbanization, population aging, and land-use changes. Longer-term fiscal assessments of climate extremes must integrate these underlying risk drivers.

IIASA researchers used the Shared Socioeconomic Pathways (SSPs) scenarios as a bridging concept to link the assessment of the public cost of demography- and climate-related expenditures. They developed a climate risk mainstreaming methodology using a stochastic debt model to assess potential fiscal flood risk in Austria. The baseline modeling results show that public debt in the country is estimated to increase from the current level of 84.5% relative to GDP in 2015, to 92.1% in 2030. Macroeconomic variability adds further risk to the country's baseline public debt trajectory, while the estimated public contingent liability due to expected flood risk is small relative to the size of economy.

The team also evaluated the likely impact of climate extremes on the sustainability of Austria's disaster fund and found that the current setup is sufficient to cover the cost of frequent-and-low impact floods but is likely insufficient to deal with the rising risk of extreme floods. The study calls for further discussions regarding reforms of the fund. IIASA researchers continue to work with the Austrian Ministry of Finance and their recommendations, which were drafted in collaboration with Austrian colleagues, have led to a first recognition of extreme weather risks in Austria's longer-term budget analysis and in the country's 2018/2019 budget report.

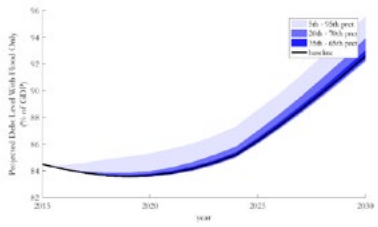


Figure 1: Stochastic debt trajectories for Austria under SSP2 scenario up to 2030. Showing 5th to 95th percentiles [1].

As many EU member states are in the early stages of designing climate policy strategies, the proposed method can support the mainstreaming of climate-related concerns into longer-term fiscal planning across the EU. This research expands the institute's work on fiscal resilience from the developing world, where IIASA has advised over 20 finance ministries.

More information ar18.iiasa.ac.at/budgetary-planning

Breaking out of technological lock-in

Policy and technological innovation for managing risks from poor water quality may be entering a phase of profound transformation brought about by the conjunction of two good ideas: resource recovery from waste flows of water and "clumsiness" in governance systems.

A viewpoint published by IIASA researchers used the theory of plural rationality – also known as the cultural theory of risk – to argue that the transformation from pollution control to resource management will require a deliberative governance process that breaks out of the closed hierarchical dominance of command-and-control water management to include the often fractious opposition. For the entire 20th century the prevailing framing of the water quality policy issue was that non-water resources were in fact pollutants to be controlled and reduced. There was substantial and deep lock-in with regard to technologies like the flush toilet, sewerage, and the centralised wastewater treatment plant, as well as in terms of water governance issues, which were typically dominated by strongly hierarchical institutions and their circle of experts.

Projects undertaken some years ago to restore the water quality in Europe's river Rhine and North America's Great Lakes, show that it was only when competing voices were admitted to the table that the problem evolved beyond previously unsuccessful hierarchical control to include entrepreneurial interests in resource recovery and egalitarian voices for nature-based solutions. According to the theory, "clumsiness" is the capacity to acknowledge and benefit from plural, contending, mutually opposed ways of framing and solving a problem. The clumsy solutions of the Rhine and the Great Lakes proved iconic in their success.

Beyond showing the value of deliberative and inclusive policy processes for driving robust transformations, the researchers examined how engineers think as a critical aspect of breaking out of technological lock-in. They identified four common schools of thought. The three most active of these are the hierarchist school with its marked bias towards complex, carefully planned, capital-intensive, centralised, and large-scale solutions. The second is the egalitarian school for which the affairs of society should reflect the marvellous workings of nature, and science should concern itself with the irreducible whole, while the individualist school of engineering thought calls for the freedom to innovate and take risks. The researchers explain that in a vibrant pluralistic society, these schools compete. Examples include competing views between freewheeling entrepreneurial, private enterprise, and government regulation, or between the "reductionist quick engineering fix" and holistic socially sensitive approaches to risk management.

An IIASA-designed stakeholder process brought the competing engineering schools together with stakeholders in Italy to co-generate a clumsy landslide mitigation plan, which has now been incorporated into policy. The team's work shows that it is indeed possible to find ways of promoting the creative interplay among more than two, mutually opposed, contending ways of framing a problem and resolving it. They argue that this should not only expand the portfolio of possible alternatives for technology-policy interventions, but could also lead to the chosen alternative being preferable to what might otherwise have happened.

More information ar18.iiasa.ac.at/technological-lock

Supporting the policy discourse around Loss and Damage

In addition to mitigation and adaptation, the concept of "Loss and Damage" is considered a third pillar in the climate policy discourse. IIASA researchers provided evidence-based insight and proposals to facilitate a step-change in this highly politicized climate policy domain.

The discourse around "Loss and Damage" (L&D) has gained traction over the last few years. Supported by growing scientific evidence of man-made climate change amplifying the frequency, intensity, and duration of climate-related hazards, along with emerging evidence that adaptation may not be feasible in some regions, the Warsaw International Mechanism for Loss and Damage was established in 2013 and supported through the Paris Agreement in 2015. Despite some advances, the debate has been broad, diffuse, and even somewhat confusing. A book [1] published in 2018 as a joint effort by the Loss and Damage Network – an IIASA-led partnership between scientists and practitioners from various institutions around the globe – provides evidence-based insight into the L&D dialogue by highlighting state-of-the-art research conducted across multiple disciplines. The publication discusses applications in practice, and provides perspective on different policy contexts and salient policy options.

The volume identifies key propositions that hold potential for advancing the highly politicized debate. One proposition suggests

that comprehensive risk analytics integrated with distributive and compensatory justice considerations provides an effective entry point for identifying a distinct L&D policy space and working towards a jointly acceptable position among negotiators from both developed and developing countries as there is currently no accepted definition of what L&D constitutes.

For the short-medium term, the authors' proposed framework takes a needs-based perspective for climate risk management beyond countries' ability to absorb risk. For the medium-longer term, they suggest the consideration of liabilities attributable to man-made climate change and its associated impacts. The authors developed the framework based on the principles of need and liability, and identified the policy space for L&D as composed of curative and transformational measures.

Transformational measures, such as managed retreat, have already received attention in discussions on comprehensive climate risk management, but according to the authors, curative action is less clearly defined, and more contested. They postulate that support for a climate displacement facility could be one policy option. For both measures, risk financing (such as climate insurance) emerges as an entry point for further policy action, as it holds potential for both risk management and compensation.

To quantify the L&D space for specific countries, the authors suggest building on a risk layering approach that segments risk and interventions according to tolerance. With many aspects of L&D being of immaterial nature, the authors propose that in principle, the current broad risk and justice-based approach can also be applied to issues like migration and the preservation of cultural heritage. The Intergovernmental Panel on Climate Change (IPCC) invited one of the book editors to coordinate the review of the state-of-the-art on L&D for its recent 1.5°C report [2].

More information ar18.iiasa.ac.at/loss-damage

Serious gaming for risk communication and engagement

IIASA researchers develop and carry out serious games and simulations around the world to engage policymakers, businesses, communities, academics, and others in exploring the challenges of reducing disaster risk, building resilience, and ultimately contributing to sustainable development.

In 2018, floods, wildfires, tsunamis, and other hazards were responsible for economic losses of US$225 billion and sadly also caused the deaths of more than 10,000 people. The UN International Strategy for Disaster Reduction's Sendai Framework calls for substantially reducing disaster risk and building resilience at all levels by 2030. This is critical for achieving the UN Sustainable Development Goals.

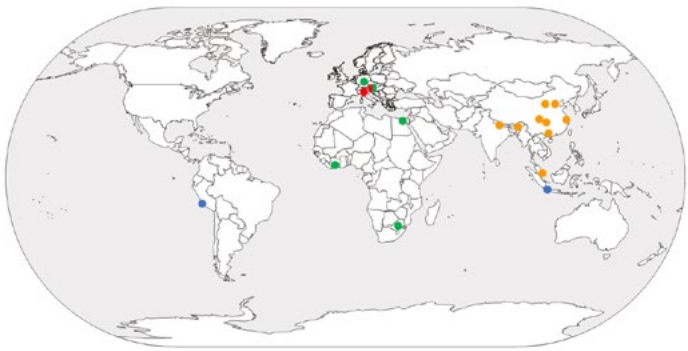
Effective communication and engagement with citizens, businesses, and policymakers are key to helping stakeholders overcome the challenges they face in taking pro-active measures to reduce risk and enhance community resilience. One challenge is the complex nature of disaster risk, which is often embedded in "wicked" contexts where both the nature of the problem and the preferred solution are strongly contested. A related challenge is overcoming the public good nature of preventive measures – the "free rider" problem. These and many other challenges can be effectively understood and ultimately addressed with the use of serious games, which can provide a simulated real-world environment for experiential learning. In this way, participants learn about the complex structure of the problem at hand, including the social complexities of interactions among multiple stakeholders with conflicting agendas, problem frames, interests, and worldviews (wicked problems) [1].

IIASA researchers conducted the first comprehensive review of 45 non-commercial disaster-risk-management (DRM) games [2], which showed their potential in helping raise risk awareness, identifying hazards, undertaking preventive actions, triggering empathy and perspective-taking, and providing a rich social experience with players collaboratively approaching and solving problems. Some limitations identified in the review included difficulties in incorporating cultural diversity and gender equality, and the necessity of strong facilitating skills.

Building on this experience, the team designed its own user-tailored games. Examples include:

- A flood resilience game that helps practitioners experience, explore, and learn about flood risk and the resilience of communities in river valleys, and identify novel policies and strategies that improve flood resilience.
- The Narubu game of many voices, which engages participants to experience the inherent difficulties of framing and solving 'wicked' water resource and disaster issues, and the limitation on evidence-based decision making in a context of multi-stakeholders with diverse worldviews.
- Forest@Risk confronts players with the challenges of environmental disasters (earthquakes and floods) faced by vulnerable forest-dependent communities to explore and learn how to simultaneously manage multiple public and common goods, emphasizing the importance of internal agreements and trust.
- Players in the Nexus Game take on the roles of policymakers tackling interconnected water-food-energy nexus challenges in a transboundary setting under drought and flood risks.

IIASA carried out DRM game sessions across Africa, America, Asia, and Europe with participants from public and private sectors, international organizations, civil society organizations, and academia. The team is also piloting their use in real-world stakeholder engagement and knowledge co-production processes.



The following games have been played in numerous locations: Flood resilience (blue), Narubu (red), NEXUS (green), Forest@Risk (orange).

More information ar18.iiasa.ac.at/risk-communication

Transitions to New Technologies

The Transitions to New Technologies Program aims to further the understanding of the drivers, constraints, impacts, and dynamics of technological change, particularly in areas that are key for global sustainability. The program disseminates policy-relevant research findings through high-level global fora and participates in major international cross-cutting research projects and assessments.

Program website

Publications

Staff

Scientific recognition

RESEARCH AREAS

Selected highlights:

Pioneering a new approach to systems transformations

Pushing frontiers in science: Rethinking demand

Technological innovations for achieving the SDGs

Engaging with science and policy communities

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Pioneering a new approach to systems transformations

One of the greatest challenges the world faces is how to limit climate change to below 1.5˚C. A groundbreaking IIASA study demonstrated the benefits of following an end-use, low energy demand (LED) strategy that does not rely on so-called negative emissions technologies.

IIASA hosts the database that the Intergovernmental Panel on Climate Change (IPCC) used to develop its Special Report on Global Warming of 1.5°C. It was while looking at this in 2017, that IIASA researchers noticed that each of the 400 global scenarios that could meet the 1.5°C target relied on negative emissions technologies. This realization resulted in a project that saw scientists from several research programs at the institute collaborating on the development of the LED scenario. Rather than focusing solely on climate change, the LED scenario instead incorporates the Sustainable Development Goals (SDGs) as a framework. The development process took just three months, attesting to the high degree of interdisciplinarity and cooperation between programs and researchers at the institute.

The LED scenario meets the Paris Agreement target of limiting global warming to 1.5°C by 2100 and is the first to do so by shrinking the energy system rather than relying on unproven negative emissions technologies, such as bioenergy with carbon capture and storage (BECCS). In the scenario, global energy use is reduced by 40% compared to today. The study [1] shows that dramatic transformations in the way we move around, heat and cool our homes, and buy and use devices and appliances in our cities can help raise living standards in the Global South to meet the SDGs while also remaining within the 1.5°C target. According to the researchers, improved living standards for all need not come with a large increase in energy demand at the expense of the global environment.

The study had an exceptional impact on both science and policy. Altmetric statistics by *Nature* show the paper ranked in the top percentile of all articles included in their sample of 250,000 publications. The LED scenario was also adopted as one of the highlighted marker scenarios for the IPCC Special Report on Global Warming of 1.5°C and was instrumental in the planning for a special chapter on Demand, Services, and Social Aspects of Mitigation (Chapter 5, Working Group III) in the ongoing Sixth IPCC Assessment Report.

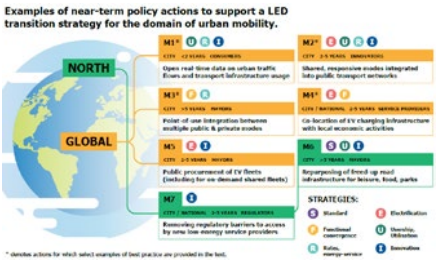


Figure 1: Examples of near-term policy actions to support a LED transition strategy for the domain of urban mobility.

In terms of policy impact, the end-use demand perspective and the policy implications of LED have been highly influential in both international as well as climate policy circles, including an initiative by the Japanese government to present an alternative demand-side policy strategy for consideration at the G20 meeting. Further impacts are expected from a detailed policy interpretation brief (Figure 1) written in 2018 to be published in 2019. This policy brief also constituted part of the contract deliverables for the external ALternative Pathways toward Sustainable development and climate stabilization (ALPS) project with the Research Institute of Innovative Technology for the Earth (RITE) in Japan.

More information ar18.iiasa.ac.at/systems-transformations

Technological innovations for achieving the SDGs

The UN Sustainable Development Goals (SDGs) aim to end poverty, protect the planet, and ensure peace and prosperity for all. A global research initiative established by IIASA provides information and guidance to policymakers for the successful implementation of these important goals.

The World in 2050 (TWI2050), an international and institute wide crosscutting initiative, released its first report [1] at the 2018 High-level Political Forum at the UN Headquarters in New York through an invited plenary presentation and three side events. The report synthesizes a holistic perspective on strategies to address all 17 SDGs in an integrated manner and on an ambitious time schedule. TWI2050 concluded that six major transformations (Figure 1) are needed to realize a holistic SDG implementation strategy in the fields of human capacity and demography; consumption and production; decarbonization and energy; food, biosphere, and water; smart cities; and the digital revolution. Research by the IIASA Transitions to New Technologies Program underpinned two of these transformations, namely consumption and production [2], and the digital revolution.

A key entry point for an integrated strategy towards the achievement of the SDGs is to view consumption and production systems in an integrative fashion, avoiding any undue isolated supply- or demand side perspectives. Research into the current systems efficiencies of resource processing systems revealed that for energy, food, water, and materials, transformation and utilization efficiencies invariably become smaller the closer the systems boundaries are extended towards final service use. A service provision focus is therefore essential for addressing the SDGs, as services provide for human welfare, whereas corresponding upstream resources, while necessary, imply multiple environmental impacts. With water embedded in food, for example, an increase in the efficiency of nutrition for human sustenance through, for instance, a reduction in food waste, translates into a six-fold leverage effect on reducing water withdrawn for input to the food supply chain (Figure 2). The effects in other resources like materials or energy in Figure 2, are of comparable magnitude, highlighting a critical entry point for SDG policies, namely a focus on efficient service provision and associated innovations in technologies, practices, behaviors, and market organization.

Researchers also empirically explored the interlinkages and synergies between transformations through digitalization, and consumption and production by looking at the resource implications (materials and energy) of digital device and service convergence [2]. Further critical interlinkages between the digital revolution and the other five transformations for the SDGs are being explored in more detail and will contribute to the TWI2050 report in 2019.

In addition to the above, researchers developed a rigorous analytical format for assessing technological options and trends as input for scenario modeling and policy analysis, and conducted two test case studies on the energy-water nexus. The first study focused on water desalination, which is highly energy intensive [3], while the second took a demand side view on agricultural irrigation technologies.

New research in the domains of social interactions [4], behavioral spillovers [5], and formative phases [6] and processes in technology innovation [7, 8], among others, further supports the research on integrated SDG implementation strategies [9, 10, 11, 12, 13, 14] and explores novel policy options.

More information ar18.iiasa.ac.at/technological-innovations-sdgs

Pushing frontiers in science: Rethinking demand

Under the 2018 thematic focus of Consumption and Production, IIASA partnered with the Research Institute of Innovative Technology for the Earth (RITE) to organize an international, interdisciplinary workshop aiming to push the frontiers of science on the conceptualization, interdisciplinary integration, and modeling of demand.

It is widely recognized that dominant disciplinary models of conceptualizing demand are often formulated at a level of intermediary goods and services, in other words, with a focus on for example, cars or gasoline, instead of on mobility. This has the effect that these models fall increasingly short in terms of both empirical explanatory power and in usefulness for novel policy approaches beyond the technological or economic realm.

In order to ultimately push the scientific frontier on concepts, models, and policy innovations addressing the demand (consumption) side of resource and technological systems, IIASA collaborated with RITE in Japan to convene a three-day international, interdisciplinary discussion workshop titled, Rethinking Demand, on the premises of the eighth century AD Todaiji Temple in Nara, Japan.

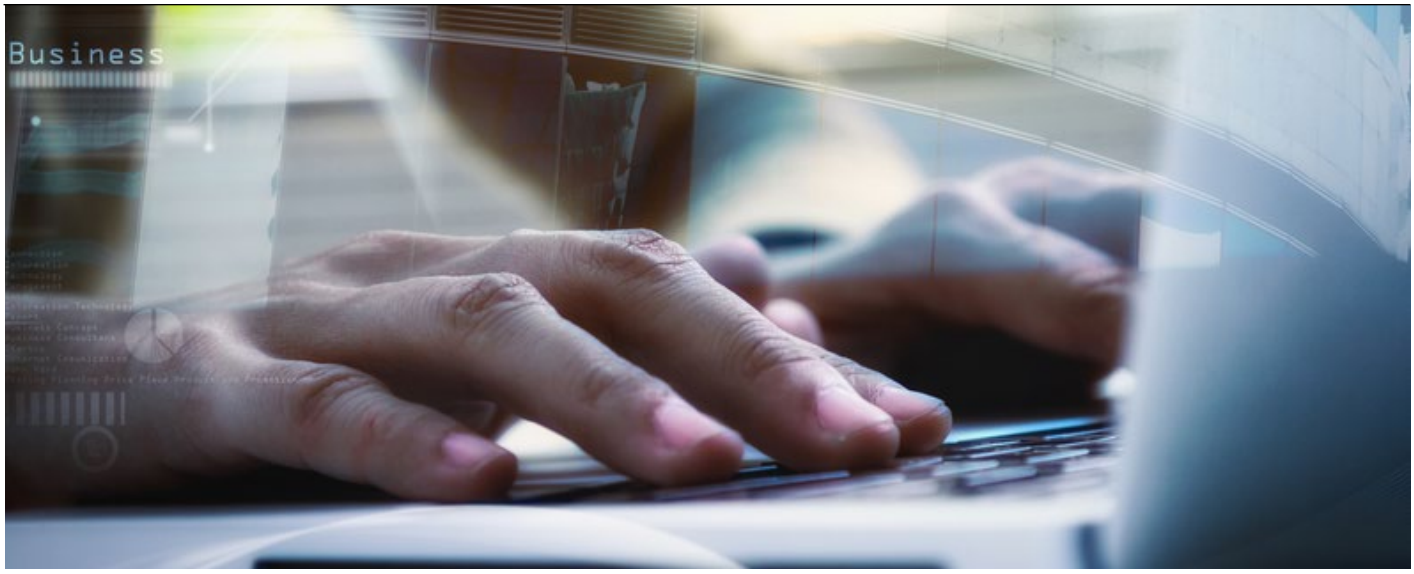
The aim of the workshop was to further an interdisciplinary dialogue on the novel conceptualization of energy demand and to provide a forum to discuss new concepts that might not be familiar across disciplines. Some of the topics highlighted during the workshop include decent living standards, shared urban mobility models, Society 5.0 concepts, digital convergence, social practice theory, time budgets and resource implications, as well as new insights and research questions from different fields, and novel conceptualizations of demand and modeling approaches.

This highly successful workshop helped to establish a new scientific community committed to a continued exchange and dialogue with the ultimate objective of providing novel conceptual and formal representations amenable to modeling. To that end, external funding for a continuation of the Rethinking Demand workshops was obtained, and a sequel event is being planned at IIASA in 2019.

The workshop, individual contributions, as well as a synthesis workshop report of the main messages and lessons learned are documented on the IIASA website. The workshop summary report also formed part of the external funding reporting for the ALternative Pathways toward Sustainable development and climate stabilization (ALPS) contract, on which IIASA is collaborating with RITE in Japan.

Participants of the international, interdisciplinary IIASA-RITE workshop on Rethinking Demand, Nara Japan.

More information ar18.iiasa.ac.at/rethinking-demand



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Engaging with science and policy communities

The Transitions to New Technologies (TNT) Program's strategy for engagement with the IIASA science and policy communities include a focus on high-level international science and policy initiatives and the dissemination of results from its research through dedicated open source web-based platforms.

Given its small size, the TNT Program relies on a few high-level high-visibility international fora and science and policy initiatives to disseminate its research findings and to engage at the science-policy interface. Key partners at the international level include the UN, the World Bank, and in particular the Global Environmental Facility, and the Intergovernmental Panel on Climate Change (IPCC). The World in 2050 (TWI2050) initiative which the program co-designed, and co-manages, and also actively participates in scientifically, involves more than 30 partners and collaborating institutions. Individual collaborations with researchers involved in ongoing TNT research involve institutions from multiple countries including Austria, China, Germany, India, Israel, Japan, Sweden, the UK, and the USA.

Documentation of the program's research output is achieved through the IIASA online publication repository PURE, as well as through a number of other online resources. The community-service database tools jointly managed by TNT and the IIASA Energy Programs have become a hallmark of the institute's mission of supporting scientific research, documentation, and dissemination, and provide the widest possible outreach with limited in-house resources. Combined, these community tools and services attracted more than 100,000 unique visitors in 2018 (an increase of close to 30% compared to 2017) and involved data downloads of some 1.7 terabytes. The use of TNT online tools has also grown substantially over the years with user demand distributed equitably across the various tools and databases offered.

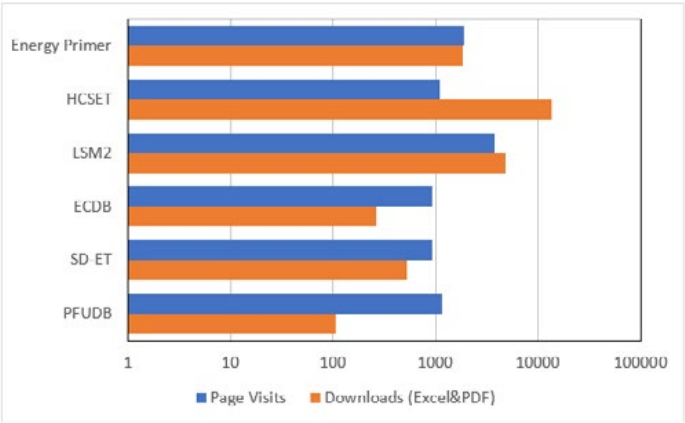

Figure 1: Use of TNT online tools and data bases (visitors and files downloaded) in 2018 (year totals). TNT models & databases: Energy Primer (educational material); Historical Case Studies of Energy Technologies (HCSET); Logistic Substitution Model 2 (LSM2); Energy and Carbon Emissions Inventories Database (ECDB); Scaling Dynamics of Energy Technologies Database (SD-ET); Primary, Final and Useful Energy Database (PFUDB).

More information
ar18.iiasa.ac.at/engaging-with-science-policy-communities

Water

Addressing complex and growing water challenges calls for a robust, interdisciplinary approach. The Water Program uses scenarios to explore how different water management policies may affect development in the face of increasing uncertainty and provides policymakers with a sound scientific basis for responding to current and future global water challenges.

Program website
Publications
Staff
Scientific recognition

Selected highlights:

Addressing uncertainty in water management

Understanding virtual water trade

Supporting sustainable agricultural strategies

Encouraging science-based policymaking in East Africa

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Addressing uncertainty in water management

Reliable access to clean water is a key aspect addressed by the UN Sustainable Development Goals (SDGs). A general decision-making framework developed at IIASA to support policy decisions on water resources management, for the first time explicitly takes into account the associated uncertainties.

Most of the SDGs are in some way affected, either directly or indirectly, by growing water scarcity problems, which are likely to be further exacerbated by factors like climate change and increased water extractions for use in, for instance, agriculture and industry. IIASA researchers analyzed the wide range of possible future conditions that could pose planning challenges for water management authorities in vulnerable regions and river basins. They identified changes in the uncertainty range of anticipated water scarcity conditions and based on this assessment, developed a general decision-making framework to support the design of policy options, which, for the first time, explicitly takes into account the associated uncertainties [1].

Options to address water scarcity include investments in water storage and transfer infrastructure, desalination plants, more efficient irrigation systems, improved crop water productivities, as well as water trade and economic incentives. As most of these solutions come at a substantial cost, it is crucial that decisions on investments and interventions for water management at all scales are based on reliable projections of future water shortages. The reliability of such projections are however subject to uncertainties related to the wide range of anticipated socioeconomic developments, climate change conditions, and methods that will apply in the future. In addition, water-sector challenges may vary considerably between countries and regions facing different levels of water scarcity under future uncertainty.

Previous assessments of future water scarcity and associated adaptation and management options were wholly based on either single models or multi-model averages. The new framework developed at IIASA, accounts for the large range of uncertainty, based on a set of 45 water scarcity projections representing different socioeconomic pathways, climate change conditions, and modeling approaches. The researchers also provided guidelines at grid-scale, thereby going beyond the commonly used country- or basin-scales.

To help understand the potential policy implications of their findings and guide the planning for large-scale adaptation strategies in coming decades, the team defined four clusters (or challenge classes), highlighting areas with potentially similar water management challenges in each. While acknowledging that water management is constrained by local conditions and that there might be few global solutions to local water management problems, they note that policies should be designed to be robust under a wide range of socioeconomic and climate conditions, but also able to adapt to conditions that both can and cannot be anticipated.

The study makes a critical contribution to future processes related to the planning and implementation of no-regret, transitional, and transformational investment options by governments, the private sector, and civil society actors. This makes the framework especially suitable for use by regional to national to multinational water authorities and water managers, as well as socioeconomic stakeholders and decision makers.

More information ar18.iiasa.ac.at/water-uncertainty

Supporting sustainable agricultural strategies

Land is an essential element of agriculture, food production, and many other human activities. Tools developed by IIASA and its partners support policymakers in the development of national, regional, and global strategies for food production that ensures the long-term sustainability of land and water resources.

The Agro Ecological Zoning (AEZ) methodology jointly developed by IIASA and the UN Food and Agriculture Organization (FAO) provides comprehensive information for rational land use planning and decision making at the global scale. Beyond Global Agro-Ecological Zoning (GAEZ), several National Agro Ecological Zoning (NAEZ) applications have also been developed.

IIASA and the FAO are collaborating under the project, Strengthening Afghanistan Institutions' Capacity for the Assessment of Agriculture Production and Scenario Development, to support the implementation of tools for NAEZ and land resource information management in Afghanistan, which is a priority country for many IIASA National Member Organizations. The objective of this EU-funded project is to improve the monitoring and analysis of agricultural systems to support food security and sustainable agricultural policies.

In 2018, IIASA implemented the NAEZ Afghanistan tool to assess the quality and availability of land and water resources in the country's 34 provinces to identify crop cultivation potentials under current and future agro-climatic conditions. The analysis underpins the design of spatially detailed strategies for the intensification of agriculture and adaptation to adverse climate change impacts. IIASA scientists also presented a one-week AEZ training workshop for specialists from the Ministry of Agriculture and other government institutions in the country, dealing with topics such as crop production, land use planning, water allocation, climate change impacts in agriculture, and rural development.

Figure 1: Suitability of rain-fed wheat in Turkey (Source: NAEZ Turkey). The map shows the suitability of current arable land for rain-fed wheat cultivation. It takes into account climatic, soil and terrain features of the land and applies CORINE Land Cover to locate the arable land.

The FAO has also been implementing a project on Agricultural Implications for Ecosystem Based Adaptation to Climate Change in Steppe Ecosystems in close cooperation with the Ministry of Food, Agriculture, and Livestock of the Republic of Turkey. The overall objective of this project is to increase the resilience of societies and steppe ecosystems to the impacts of climate change and to increase national capacity and awareness for medium and long-term ecosystem based adaptation plans. IIASA was tasked with establishing a NAEZ tool for Turkey as part of this project.

NAEZ Turkey includes current and historical information on climate, soil, terrain, and land cover to conduct an agro-ecological assessment of crop suitability and productivity, and has been used to analyze the impacts of climate change and other environmental drivers across the country. The tool and assessment provided by IIASA was completed in 2018 and presented at a final project workshop held in Konya, Turkey, in December 2018.

This research has uncovered important consequences for future agriculture of especially the Anatolian steppe region. Climate change will alter agro-ecological conditions due to an anticipated deterioration of soil moisture conditions and possibly severe temperature related negative impacts on especially wheat and barley, which are Turkey's most important food staples. As a consequence, water management will be ever more important for sustaining agriculture in the country's steppe regions.

More information ar18.iiasa.ac.at/agricultural-strategies

Understanding virtual water trade

It seems like an intuitive solution for water-scarce regions to alleviate water stress by simply importing products that require a lot of water to manufacture. IIASA researchers investigated why real trade patterns do not always support this theory.

Virtual water trade refers to the unseen flow of water if food or other commodities are traded from one place to another. The virtual water hypothesis states that water-deficient regions or countries could alleviate water stress by simply importing water-intensive products – in other words, products that require a lot of water during the production process – from water-abundant regions or countries. Although trading patterns often don't support this hypothesis, there is a lack of research that explores the reasons behind this. To fill this gap, a team of researchers from IIASA quantitatively introduced comparative advantage theory to track the driving forces of net virtual water exports. They based this on the distribution of resource productivity over space and time, and the opportunity costs of land, labor, and water use in agricultural and non-agricultural sectors across Chinese provinces between 1995 and 2015.

China was chosen as the research focus area for several reasons.

First, the country's regional development shows a persistent imbalance with pronounced disparity in factor productivity (the portion of output not explained by traditional inputs like labor and capital used in production) and differences in resource endowment (the amount of land, labor, and capital a country can use for manufacturing). Regional specialization and economic booms have led to significant increase in interregional commodity trade as well as virtual water flows embodied in trade. Second, as the largest exporting country and the second largest economy in the world, China's exports present a significant part of the global economy. The dynamics of interregional trade structures within China could therefore have significant implications for global trade and the global economy.

The team's findings revealed that regional differences in land productivity between the agricultural and non-agricultural sectors are the main forces shaping the pattern of virtual water flows across regions, whereas other resources such as labor and water have played a less important role. The regions that tend to show a net import of virtual water flows, such as southern China, are also the ones that have high opportunity costs for their land resources. These regions also gain higher shares of value added by using their land for nonagricultural production and importing agricultural products, even if they have fertile land and rich water resources. The results suggest that efforts to increase the land productivity of agriculture in the southern regions would contribute to reducing water scarcity in the North and Northeast China Plains.

The study is an excellent example of how an innovative coupling of economic theories with natural resource management can explain the counter-intuitive phenomenon of the virtual water flows in trade from water-scarce regions to water-rich regions in the context of China.

More information ar18.iiasa.ac.at/virtual-water

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Encouraging science-based policymaking in East Africa

A key goal of integrated water resources management is to balance supply and demand for all water users across different economic sectors while safeguarding the environment. IIASA research supports the incorporation of water science into policy, planning, and applied management issues.

Water scarcity intensifies when demand increases and availability in terms of quantity and/or quality decreases. The IIASA Water Futures and Solutions Initiative (WFaS) identifies and tests solution pathways across different economic sectors and supports the co-design of future development scenarios and possible solution options through stakeholder engagement. This provides important input for supporting mid- to long-term water management and planning based on informed decision making.

The initiative focused on East Africa with the extended Lake Victoria Basin as a key research area, aiming to understand the future water balance in the region toward 2050. The team used an integrated modeling framework combining the IIASA Community Water Model and the Extended Continental-scale Hydroeconomic Optimization model (ECHO), under two future development scenarios. Based on the East Africa Vision 2050 and the development visions of the East Africa Community member countries, the team developed an East Africa Regional Vision Scenario, while the second scenario, Business As Usual, is based on the Shared Socioeconomic Pathways (SSP2).

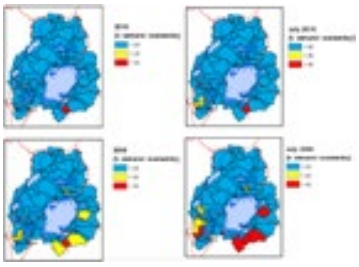

Figure 1: Change of the Water Exploitation Index for the Lake Victoria Basin from 2010 to 2050. The panels indicate how total water abstraction puts pressure on water resources. Severe water stress can occur in regions with an index over 40%.

Rapid economic development and population growth expected up to 2050 will lead to a sharp increase in water demand across all economic sectors. In this particular study area, much of the demand is expected to be offset by an increase in water availability due to climate change effects like increased precipitation, along with surface water runoff due to land use changes. According to the researchers, this may still lead to major water imbalances at the local scale and in particular areas of the studied basin.

The results of the two scenarios show moderate water scarcity when measured using the Water Exploitation Index (Figure 1) and high water scarcity when measured using the Water Crowding Index (Figure 2). Uncertainties in the modeling results are mainly attributed to the projection of various drivers such as irrigation area expansion, future water use efficiency parameters, and climate change effects resulting from the use of general circulation models.

The project is funded by the Austrian Development Agency (ADA) and the Austrian Federal Ministry of Sustainability and Tourism. The results are helping the Lake Victoria Basin Commission and its member states (Burundi, Kenya, Rwanda, South Sudan, Tanzania, and Uganda) to make science based water resource management decisions. Stakeholder workshops presented as part of the project attracted researchers and practitioners from across the region [1]. In December 2018, the results were also presented and discussed at a workshop that included training participants on the analysis and interpretation of the modeling results [2].

The team will expand their work through a project titled, Scaling out Resilient Water and Agricultural Systems (scaleWAYS), which looks at up-scaling options for water and land management practices for the resilient and sustainable intensification of agricultural production and food systems in the extended Lake Victoria Basin [3].

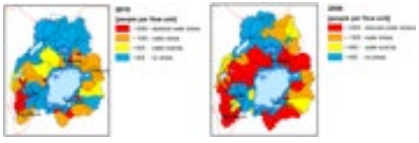

Figure 2: Change of the Water Crowding Index for the extended Lake Victoria Basin from 2010 to 2050. Below 1,700m³/capita/year water stress appears regularly, below 1,000 water scarcity is a limitation to economic development and human health, and below 500 water availability is a main constraint to life.

More information ar18.iiasa.ac.at/policy-east-africa

World Population

The World Population Program is renowned for its work on the changing size, distribution, and educational composition of the world's population and the effect of these changes on sustainable development. The program's research complements the institute's work on environmental topics and provides insights on the resilience of populations and how human health and wellbeing are being affected.

Program website
Publications
Staff
Scientific recognition

Selected highlights:

Accounting for diversity in population projections

Forecasting world population and migration

Rethinking the predictors of longevity

New survival-based measure for wellbeing

Accounting for diversity in population projections

Researchers from IIASA and the Asian Demographic Research Institute have shown that explicitly accounting for differences within populations significantly influence future population projections. Their work contributes to current debates in population forecasting and more broadly to social and economic forecasting models in general.

Users of population data in many sectors commonly use data without considering differences in the behaviors of populations in different regions of a country. Researchers working on a collaborative study of population forecasts for India however, realized that, as India is an extremely heterogeneous sub-continent, it should not be treated as a uniform entity simply because it is one nation.

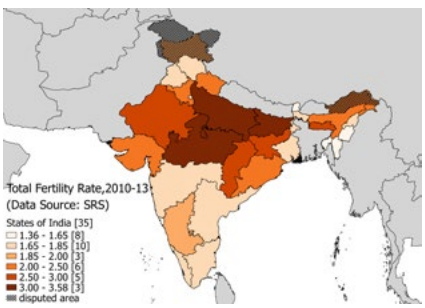

Figure 1: Total fertility rate across states of India for 2010-2013 (Data source: SRS).

To account for the diversity between different areas of the country, the team designed a study that pioneered a five-dimensional model of differences in the Indian population, including rural or urban place of residence, state, age, sex, and level of education. The model was used to show the population projection changes within scenarios that combine different levels of these factors, and revealed that forecasts over the coming decades strongly depend on which sources of differences between regions are explicitly included in the model.

The results show that a much higher population projection emerges from a model that combines projections for individual Indian states as opposed to the overall national projection, since states with higher fertility rates eventually add up to a higher national population projection. If the projection is carried out while only explicitly accounting for age and sex, influential factors like higher levels of education, which is in turn associated with decreased fertility, are omitted. The researchers explain that because education levels have increased over time across all of India, and are associated with a lower fertility rate, the same projection may predict a drastically smaller population when accounting for education and increasing urbanization. When both effects are combined, the influence of education appears to dominate, resulting in a lower population projection.

This prompted a further investigation into future education trends, which revealed that if education were to stay at its current level, the population would increase slightly more than if education improved over time. The difference between projections highlights the critical importance of deciding which demographic measures to include in a projection model, and at what rate of change. At the most general level, the research reveals the importance of considering differences within sub-national populations, and recognizing that they are at different stages of a general development. The team conclude that in addition to age and sex, education should be routinely included in population forecasts because of its well-established implications for improving the economy and quality of life, while reducing population growth and mortality rates.

The researchers believe that continuously improving population projections can help planners and support increased investment in education and human resources as countries continue to develop.

They have invited decision makers to approach them for collaboration on more future narratives, more in-depth analyses, or to use their research as input for policy work.

More information ar18.iiasa.ac.at/diversity

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Rethinking the predictors of longevity

Researchers from IIASA and the Vienna University of Economics and Business have challenged the popular view that income and medical interventions are the main drivers of health, and showed that improving education is the main driver.

Rising income and the subsequent improved standards of living have long been thought of as the most important factors contributing to a long and healthy life. This belief has been underpinned by various theories including the widely used Preston Curve, which illustrates the upward trend in life expectancy with increasing GDP. The curves shift upwards over time, which has been explained by better healthcare. A lesser-known alternative theory however, suggests that low mortality does not come as an unplanned spin-off from economic growth but rather results primarily from higher female autonomy associated with better education.

In their study [1], the researchers tested the two opposing hypotheses and found that a person's level of education is in fact a much better predictor of life expectancy. The team used global data from 174 countries from 1970–2015 and plotted life expectancy against the mean years of schooling of the adult population. The resulting curve is more linear, supporting their conclusion that education is a much better predictor. There is also no upward shift of the curve requiring explanation by other factors. The data was subjected to multivariate analyses to validate the findings and the same link was found when the curves considered child mortality instead of life expectancy.

Knowing whether income or education is the most important underlying determinant of increased life expectancy is important in terms of setting policy priorities in both developing and industrialized countries. While one would ideally promote both of these goals along with good health services, reality often necessitates a choice between different options. Understanding which aspect will have a bigger effect, could help policymakers decide between directing funding to programs that directly promote income growth or those that enhance school enrollment and quality of schooling.

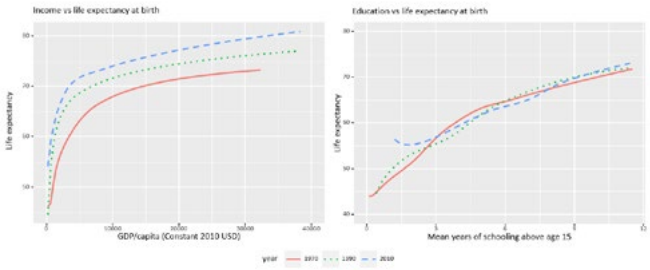

Figure 1: Curves showing the relationship between income and life expectancy (left) and between education and life expectancy (right) [1].

The researchers point out that better education leads to improved cognition and in turn to better choices for health-related behaviors. Recent decades have seen a shift in the disease burden from infectious to chronic diseases, the latter of which are largely lifestyle-related. As time goes on, the link between education and better health choices, and therefore life expectancy, will become even more apparent.

Previous lines of research at the Wittgenstein Centre, a collaboration between IIASA, the Vienna University of Economics and Business, and the Vienna Institute of Demography of the Austrian Academy of Sciences, have emphasized the importance of improving education for poverty eradication and economic growth, as well as the ability to adapt to climate change. These findings further support the call for improved access to education.

More information ar18.iiasa.ac.at/longevity

Refugees arriving in Greece in dingy boat from Turkey. © Anjo Kan | Dreamstime

Forecasting world population and migration

When fertility levels are low, as is currently the case in Europe, international migration becomes the main factor influencing population growth. However, research shows that in terms of economic consequences, the size of the labor force and productivity matter more.

A book published in 2018 by researchers from the Centre of Expertise on Population and Migration (CEPAM) – a collaboration between IIASA and the European Commission's Joint Research Centre (JRC) – examined potential future scenarios of population trends across the world [1]. The team looked at the population outcomes for 201 different countries, based on three different migration scenarios for each country, in addition to various fertility, mortality, and education scenarios.

Previous demographic assessments have only considered age and sex in population trends, while this study also factored in educational attainment and labor force participation for EU member states. According to the researchers, migration should be seen as an integral part of population dynamics, which is why in their analysis, they

considered it in the context of alternative possible scenarios for all countries of the world over the rest of this century.

In the medium scenario, for instance, world population would continue to increase until 2070–2080, reaching 9.7 billion before starting to decrease. This increase is higher than previously thought, largely due to a faster decline in child mortality in Africa. An alternative scenario assuming rapid social development, and especially better levels of education for women, would lower fertility rates with a peak population of 8.7 billion reached in 2055–2060. Stalled social development and lower levels of education on the other hand, result in higher fertility rates and the population continuing to climb over the century, reaching 13.6 billion in 2100.

These effects will of course not be the same for all regions of the world. Under the medium scenario, for example, the population of the European Union will marginally increase to around 512 million people by 2035, largely due to immigration. Following this initial increase, there will be a decline as fertility rates are low with significant aging.

Interestingly, the findings indicate that the available labor force does not necessarily diminish if female participation increases.

In Sub-Saharan Africa, the population under the medium scenario is likely to double by 2060, to around 2.2 billion people. With stalled social development and a lack of expansion in terms of education, this could even rise to 2.7 billion, which would in turn lead to widespread poverty and high vulnerability to climate change, with serious implications for potential emigration.

The scenarios developed will help policymakers face a broad range of challenges, from the economic consequences of population aging, to setting development priorities. The results highlight that within certain bounds, future trends in population are not a given and can still be influenced by policies in the longer term, while migration itself can most easily be influenced by policies in the short term.

More information ar18.iiasa.ac.at/forecasting

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New survival-based measure for wellbeing

IIASA researchers have introduced a new, simple measure for human wellbeing across countries that for the first time takes inequality in lifespans into account to produce reliable comparisons of survival-based wellbeing across countries, both in the past and the present.

Imagine an extreme scenario where half of a country's population live until the age of 90, but the other half die at 30. Using conventional methods, the life expectancy of that population will be put at 60 years – the same as in the arguably better situation where all members of the population lived to age 60. The Human Life Indicator (HLI) developed by researchers from IIASA can be used to make a distinction between these two scenarios.

Early attempts to quantify wellbeing focused solely on economic factors, such as Gross National Income per Capita. The more comprehensive Human Development Index (HDI) created by the UN in 1990, for example, added education and life expectancy as additional indicators and, despite being criticized for its statistical and conceptual flaws it is still widely used today. According to the researchers, one of the problems with the HDI however, is the redundancy of the three dimensions considered. They explain that dropping the education and economic dimensions in the HLI leads to a significant simplification without a notable loss of information.

The researchers found that their newly developed index sometimes produces different rankings of countries than the HDI. Norway, for instance, has been leading the HDI ranking for decades, in part due to their income from North Sea oil and gas, but it places 9th in the world when ranked according to the HLI. According to the researchers, this shows that the country's high income has not been sufficiently translated into longer and more equal lifespans for its people. Similar disparities between the HDI and HLI rankings can be found for other developed countries and is publicly available on the IIASA website.

The HLI expresses wellbeing in terms of years of life, similar to life expectancy at birth but, unlike any other current measure, it takes not only the mean value into account, but also inequalities in longevity. Another advantage of the new index is that it can be calculated even when information about education and economic wellbeing is not available, which means that it can provide a measure for human development that goes back further than the introduction of the HDI in 1990. By evaluating the wellbeing in selected countries over time,

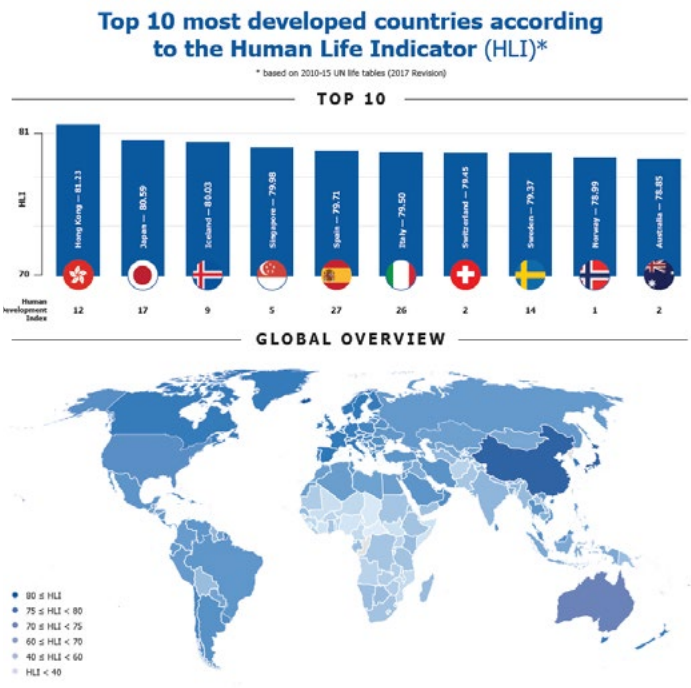

Figure 1: The top 10 most developed countries according to the Human Life Indicator (HLI) as based on the 2010-2015 UN life tables.

the researchers also show that the behavior of the HLI reflects major political and economic events across the world in the last century, such as the world wars in European countries, or the Vietnam war in Asia. This can be useful in assessing progress towards the UN Sustainable Development Goal for reduced inequality (SDG10).

The researchers hope that their work will be useful in furthering discussions on how we think about the wellbeing of countries.

More information ar18.iiasa.ac.at/wellbeing

Projects and initiatives

IIASA has several interdisciplinary research projects and initiatives aimed at achieving true sustainability through innovative approaches that link diverse dynamic systems and provide science-based insights to help policymakers make informed decisions about the global issues we face today.

Informing robust, sustainable Arctic policies

The IIASA-led Arctic Futures Initiative (AFI) brings a systems analysis perspective to the future of the Arctic and provides stakeholders in the region with expertise on scenarios, modeling, and integrative techniques that can contribute to robust policies informed by science.

In 2018, the AFI started a new project co-funded by IIASA and the Ministry for Foreign Affairs of Finland. The Analysis and Synthesis Report Project focuses on analyzing and synthesizing strategies, policies, and programs on the Arctic as it relates to Arctic and non-Arctic nations, as well as to the Arctic Council's chairmanship programs and declarations. The ultimate aim of the project is to deliver a comprehensive report based on a holistic approach to policies and strategies for the entire region. The final report will be published in 2019.

The Arctic Circle Assembly is the largest meeting for international dialogue and cooperation on the future of the Arctic. In 2018, IIASA co-organized three successful breakout sessions as part of the proceedings, respectively titled, Interplay between science, politics, and business; Changing Arctic – Foreseen ecological and socioeconomic impacts and feedbacks; and Third pole as complex socioecological system. AFI researchers also participated in several other events such as the Russian International Affairs Council's Round Table on Arctic Security, the 13th Arctic Parliamentary Conference, and the Shanghai Forum.

More information www.iiasa.ac.at/arctic

Working towards stronger European-Eurasian economic ties

An IIASA-led project analyzed prospects for enhanced economic ties between the EU and the Eurasian Economic Union and produced recommendations to improve economic cooperation in the region.

Despite considerable interest in strengthening economic ties between the EU and the Eurasian Economic Union (EAEU), progress is hampered by political tensions between the EU and Russia. The lack of political engagement between the European Commission and the Eurasian Economic Commission is also creating uncertainty for business. Through the Challenges and Opportunities for Economic Integration within a wider European and Eurasian Space project, IIASA serves as a unique, depoliticized platform where key stakeholders can engage in evidence-based dialogue.

In 2018, the project published three reports containing analyses and recommendations in several important areas:

The first report compared product standards and technical regulations in the region, and revealed that the EAEU has already adopted international standards more fully than previously realized. This creates a possibility for reducing non-tariff barriers between the EU and EAEU through, for example, mutual recognition agreements.

The second report on foreign direct investment highlighted that capital flows between the EU and Russia are declining. In the short-term, reducing administrative barriers could realistically help to improve the situation.

The third report looked at trans-Eurasian land transport corridors and argued that enhancing trade between Europe and Asia will require increased capacity, the removal of infrastructure bottlenecks, harmonization of regulatory environments, and enhanced associated investments.

The reports were presented at several high-level conferences and other events in Europe and Russia.

More information www.iiasa.ac.at/economicintegration

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Facilitating integrated solutions for water, energy, and land

The Integrated Solutions for Water, Energy, and Land (ISWEL) project is a partnership between IIASA, the Global Environment Facility, and the UN Industrial Development Organization. The project aims to develop tools and capacities for the cohesive management of water, energy, and land resources.

In 2018, the ISWEL team engaged with stakeholders from the Indus and Zambezi basins, both of which are facing multiple development and environmental challenges. Their main goals were to identify sectoral challenges from the perspective of the different riparian countries; cocreate a number of development pathways and scenarios for more desirable futures; and develop capacities around nexus research and management.

In the Indus basin, IIASA organized two national consultation meetings in close collaboration with local partners and cohosted the Annual Indus Basin Knowledge Forum with a number of international partners. In the Zambezi basin, the project team organized a Scenario Planning Workshop in collaboration with the Zambezi Course Commission and its national stakeholder network.

These engagement activities have facilitated cross-sectoral and transboundary knowledge exchange among stakeholders and are helping to mainstream the nexus approach into basin policy agendas. The stakeholder information is being incorporated into integrated assessment modeling frameworks developed at IIASA to produce quantitative stakeholder-driven scenarios.

More information www.iiasa.ac.at/iswel

© Jason Nemirow | IIASA

Communicating science through art

The IIASA Science and Art Project explores unique ways to transmit scientific insights more effectively to a wide audience in order to drive a sustainable transformation in the way that people think and act.

In 2018, two projects involving scientists and artists culminated in well-received, artistic performances. Dancing with the Future, a performance that entailed choreographing a scientific paper, was conceived in collaboration with Harvard University's Program for Evolutionary Dynamics. The piece premiered at the International Conference for Sustainable Development as part of the UN General Assembly week in New York. It explored mechanisms of cooperation and asked the audience to make decisions around how much resources we leave behind for future generations. These decisions were then enacted on stage allowing the audience to visually experience and reflect on the possible impacts of their choices.

The second performance titled Migraspectives was presented at the opening of the Summer School on Evidence and Policy co-organized by IIASA and the European Commission's Joint Research Center. The performance tackled the current debate on migration through the lenses of diverse and often conflicting world views and led the audience of researchers and policymakers from over 40 countries through a solution finding process aiming to reach an agreement despite deep-rooted differences.

More information www.iiasa.ac.at/arts

© Damian322 | Dreamstime

Achieving a sustainable future

The World in 2050 (TWI2050) is a global research initiative established by IIASA that aims to address the full spectrum of transformational challenges related to achieving the UN's 17 Sustainable Development Goals (SDGs) in an integrated manner.

As it stands, the world is not on track to achieve the SDGs. More than 2 billion people do not have access to modern cooking and sanitation, while almost a billion people do not have access to electricity or sufficient food supplies. These are often also the people who are the most vulnerable to the negative effects of climate change and biodiversity loss. A transformation towards a more sustainable future that leaves no one behind needs immediate ambitious action.

In a major report launched by the TWI2050 initiative at the UN High-level Political Forum in New York in 2018, researchers showed that such a transformation is possible with strong political commitment. The transformations presented in the report titled, Transformations to Achieve the Sustainable Development Goals, comprises human capacity and demography; consumption and production; decarbonization and energy; food, biosphere, and water; smart cities; and the digital revolution. These provide a way to achieve the SDGs in a manageable way.

According to researchers at IIASA, the report provides policymakers with invaluable new knowledge to inform action and commitment towards achieving the SDGs, thereby resolving some of the 21st century's greatest challenges. Key elements include investments in capable public institutions, collaboration between active civil societies, science, and the private sector, and the formulation and implementation of holistic and long-term multi-stakeholder action plans and roadmaps.

More information www.iiasa.ac.at/twi2050

Education and training

IIASA remains committed to strengthening the knowledge and abilities of researchers in systems analysis by training early-career researchers and demonstrating the value of its integrated models in workshops around the world. The Young Scientists Summer Program and postdoc programs in particular, provide vital capacity building in this field.

Young Scientists Summer Program

For three months every summer, the flagship Young Scientists Summer Program (YSSP) provides an opportunity for around 50 to 55 PhD students to work alongside IIASA researchers. During their stay, each participant is required to prepare a research paper. Many of these papers are published in prestigious journals. Since 1977, over 1,970 young scientists from 87 countries have benefitted from the program. The 2018 program hosted 52 participants from 27 countries.

2018 program

Participants | Biosketches and abstracts | Proceedings

2018 YSSP Awards

IIASA has instituted two annual awards for exceptional young scientists participating in the YSSP. The Peccei Award is awarded in recognition of rigorous research that makes a policy contribution, while the Mikhalevich Award is given to students who use mathematical tools to solve real-world questions. The recipients of these awards return to IIASA for another three months.

Matt Cooper received the Peccei Award for his study "Which children are most vulnerable to climate change? Mapping the effects of meteorological extremes on child stunting". Cooper is a PhD student at the University of Maryland, USA.

Jiamin Ou received the Mikhalevich Award for her paper "China's export industries and their contributions to ground-level Ozone pollution". Ou, originally from China, is a PhD student at the University of East Anglia, UK.

An Honorable Mention goes to **Davit Stepanyan** for his study "Application of Gaussian Quadratures in the Global Biosphere Management Model (GLOBIOM) as an efficient approach to uncertainty analysis". Originally from Armenia, Stepanyan is a PhD student and research associate at Humboldt University in Berlin, Germany.

IIASA Postdoc Program

Postdoc opportunities at IIASA allow early-career scientists to research a topic related to the scientific agenda at IIASA and hone their skills in systems analysis. IIASA postdocs are funded with support from the institute and one honorary fellowship established in honor of Dr. Peter de Jánosi, IIASA Director from 1990 to 1996.

In addition to the above, IIASA has been establishing bilateral postdoctoral fellowship programs funded by National Member Organizations (NMOs) since 2008.

These programs are an effective way for NMOs to increase the number of its nationals who are postdocs at IIASA, and to develop expertise in systems analysis among its researchers. IIASA currently has bilateral programs with Brazil, China, Finland, Mexico, and the Republic of Korea, and discussions are underway with the United Kingdom about establishing a scheme.

In 2018, there were a total of 26 postdocs at IIASA. This included 13 funded by IIASA, 7 funded by NMO bilateral postdoctoral fellowship programs, 2 funded by the Peter de Jánosi fellowship program, and 1 funded by the Luis Donaldo Collosio fellowship program.

Along with the Brazil bilateral postdoc program, IIASA established a doctorate-sandwich program funded by the Brazilian NMO. During 2018, IIASA hosted three PhD candidates from Brazil who spent time developing their doctoral research program.

Postdocs at IIASA in 2018

Map showing the diverse array of nationalities of IIASA postdocs and participants of the Young Scientist Summer Program. The interactive online version gives a full list of participants for each country.

Watch the YSSP video >

Southern African Systems Analysis Centre

In 2016, the South African National Research Foundation and the country's Department of Science and Technology, in collaboration with IIASA, launched the Southern African Systems Analysis Centre (SASAC), with the aim of expanding systems analysis capacity in the region. The center is currently hosted by a consortium of four South African universities, namely the Universities of Limpopo, Stellenbosch, the Western Cape, and the Witwatersrand.

SASAC provides a dedicated bursary program with annual calls for South African PhD students based at South African universities to pursue their studies with a supervisor experienced in systems analysis. The center also offers an annual capacity-enhancement program for South African and international postdoctoral researchers.

In 2018, 24 students received scholarships, and 20 postdoctoral researchers attended the 2018 three week capacity-enhancement program.

Building systems analysis expertise

In 2018, IIASA scientists hosted or coordinated 89 events worldwide, including a number of workshops and activities designed to build capacity in systems analysis. Below is a small selection of these activities.

East Africa future water scenarios workshop, Uganda

Demographic analysis with applications to aging societies, Thailand

Water nexus policy strategic planning workshop, IIASA

Training workshop on the GAINS model for experts from Eastern Europe, Caucasus, and Central Asia, IIASA

Summer school on evidence and policy, IIASA

Water modelling approaches for Egyptian academics, Egypt

Workshop on haze and biomass burning in Asia, Indonesia

See all 2018 events

Our people

The people at IIASA are its most valuable asset and the institute continues to attract and retain world-class talent. In 2018, 395 researchers from 50 countries worked at the institute, gaining access to new perspectives, methodologies, and funding, which also helps build the systems analysis capacity of their home countries.

People management

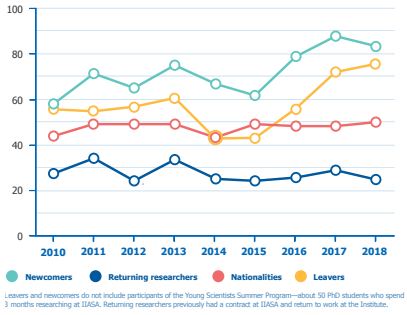
Human capital management is a high priority at IIASA following a period of rapid expansion of the numbers of researchers and staff working at the institute.

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.

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).

In 2018 a new staff performance appraisal system was introduced and the first cycle completed. In addition, new policies and strategies for the management of human resources at IIASA were developed. These include new policies on merit increase procedures, retirement planning, compensation and benefit structures, levelling and job grading, compliance with new legal regulations in Austria as well as EU legislation. In light of the General Data Protection Regulations which came into force in May 2018, the Human Resources department adapted all relevant rules and policies. A legal review of contract types was initiated in 2018 in order to set up a new contractual framework for the differing types of staff members at IIASA to support the institute's mission and vision. During 2019 a campaign will be run to define IIASA's core values for the future.

Number of researchers employed and the flow of existing researchers into and out of IIASA in 2018

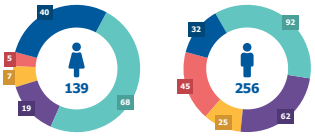


Leavers and newcomers do not include participants of the Young Scientists Summer Program—about 50 PhD students who spend 3 months researching at IIASA. Returning researchers previously had a contract at IIASA and return to work at the Institute.

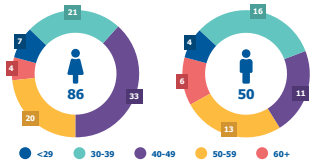
240
Full time researchers

155
Part time researchers

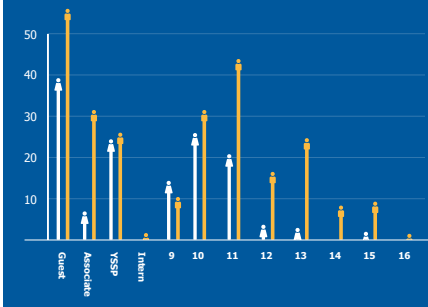
Researchers by age and gender in 2018



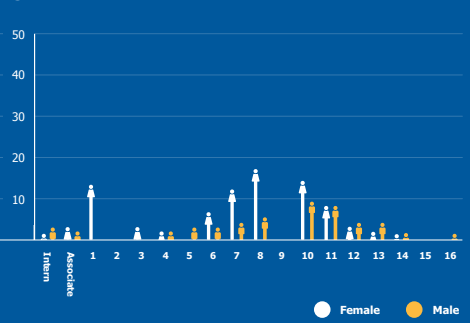
Support staff by age and gender in 2018



Researchers by level of employment and gender in 2018



Support staff by level of employment and gender in 2018



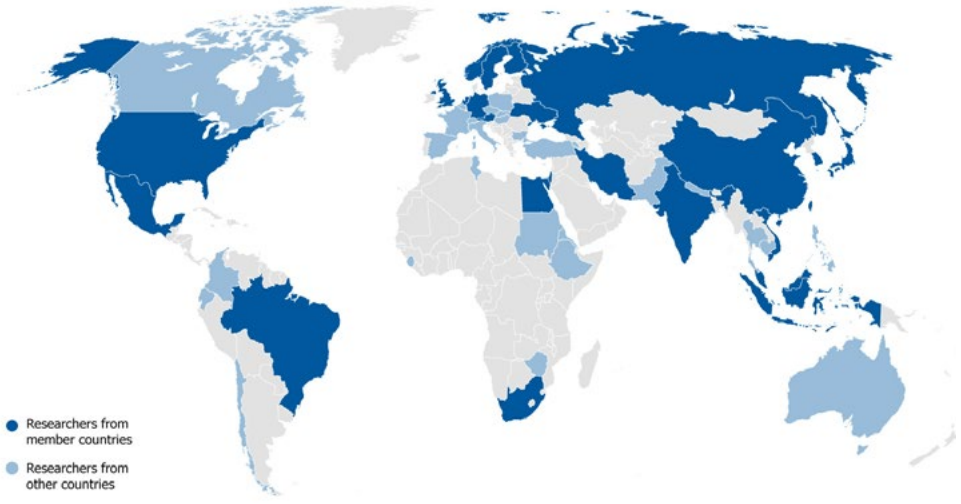
Category 9 is junior scientific staff with a bachelor's degree or above, working as scientific support. **Categories 10 -16** are experienced research staff (postdocs, research scholars, program directors, the deputy director general, and the director general), with an advanced university degree (minimum at level 10 is a Master's degree). Young Scientists Summer Program (YSSP) participants, associates, and guest research scholars are listed separately.

Categories 1-8 are general service staff in procedural or operational roles. **Categories 10-16** are professional staff with analytical, evaluative, and conceptual roles, with a degree or relevant work experience. Interns and associates are listed separately.

IIASA guidelines and regulation for good scientific practice

The IIASA guidelines and regulations for good scientific practice are intended to help avoid 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 2018.

In 2018, 395 researchers from 50 countries worked at IIASA



Diversity and equality

Many of the characteristics that make IIASA unique, as articulated in its Charter, also present challenges for both the attractiveness of IIASA as a place to work and for the retention of high-quality employees. IIASA's internationality, while being a distinct advantage, also raises challenges in terms of managing cultural, social, and geographic diversity.

As an international research institution, IIASA was founded with a commitment to the principles of equal opportunity, anti-discrimination, gender balance, cultural accommodation, and geographical distribution in its hiring, promotion, and administrative practices. With a staff made up of over 50 nationalities, it is an inherently diverse institution. However, like all diverse organizations, it struggles with issues of equity, tolerance, and promotion of diversity at all levels of the institutional structure.

In 2017 the Council issued Resolution 696 supporting the formation of a holistic diversity strategy to be developed by IIASA with the assistance of an external consultant. The initial terms of reference include an assessment of diversity, a benchmark of diversity compared with other organizations, and the development of a vision for a more diverse workforce at IIASA. The IIASA management will report back to Council on the ongoing progress and planned actions by June 2019.

Furthermore, to underline the importance of offering equal opportunities, IIASA explicitly states in all job advertisements its commitment to a working environment that promotes equality, diversity, tolerance, and inclusion within its workforce and encourages qualified candidates from all genders, and religious, ethnic, and social backgrounds to apply.

Age, gender, and employment at IIASA

In 2018, IIASA continued to provide the service of the Institute Counselor, a Human Resource Consultant and Cognitive Behavior Therapist, as a work psychologist to provide training and counseling related to cultural and social diversity and work environment issues. The services of the Institute Counselor have been a well-used resource, appreciated by staff who can obtain confidential counsel. The Institute Counselor is an impartial, trusted individual who can offer IIASA staff support with the challenges and opportunities related to living and working in an international scientific environment. Twice yearly anonymized updates and statistics are provided to management in order to address any issues that may arise.

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 outlines the responsibilities of IIASA, staff, and management in these areas. Employees 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.

In 2018 nine incidents of misconduct were reported to the Human Resources department, three disciplinary measures were taken by the management after finalization of the investigations.

Works Council

In 2018 a Works Council was established at IIASA in accordance with Austrian employment law. The Human Resources department and the newly instated Works Council worked on developing channels for communicating legally required and institutionally beneficial information between the institute (as employer) and employees. Possible disputes arising out of miscommunication and misunderstandings were able to be resolved amicably by collaboration between the Human Resources department and the Works Council.

Partnership

The Human Resources department entered into a mutually beneficial partnership with the International Anti-Corruption Academy (IACA) in 2018, to promote an exchange of services, expertise, and information.

Network and collaborators

In 2018, 395 researchers from 50 countries worked at IIASA. In addition, IIASA has a large research network of collaborators, alumni, and visitors from different countries and disciplines.

4,570
alumni from 99 countries

190
advisory boards and steering committees incorporating IIASA researchers

150
externally funded projects where IIASA was lead or partner

819
research partners in member countries

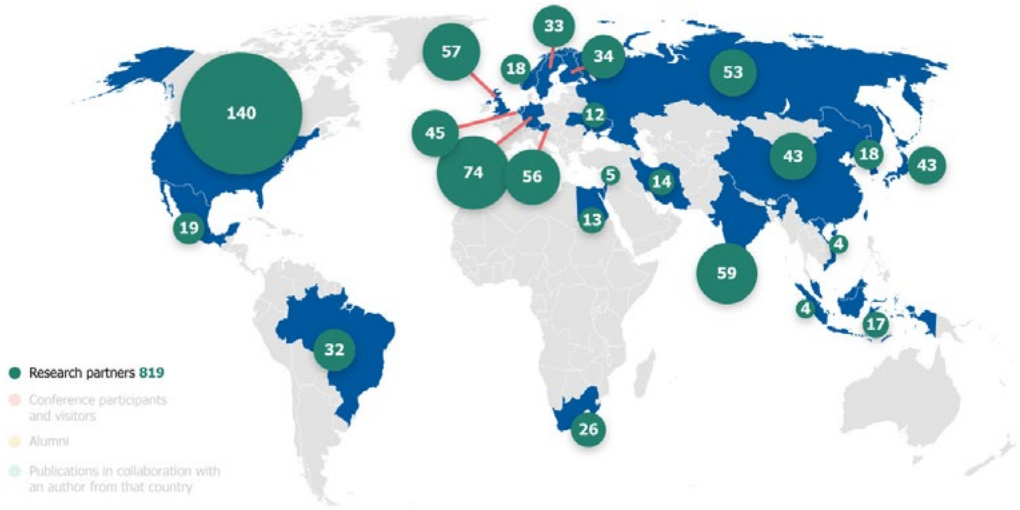
IIASA Network

- **Research network** – IIASA has a worldwide network of collaborators who contribute to research by collecting, processing, and evaluating local and regional data that are integrated into IIASA models. The institute has 819 research partner institutions in member countries and works with research funders, academic institutions, policymakers, and individual researchers in national member organizations.
- **Visitors** – In 2018, 1,605 associates and scholars visited IIASA to do research, collaborate with the institute's research programs, and attend IIASA-organized events. Of these visitors, 1,079 were from member countries.
- **Meetings and events** – In 2018, IIASA scientists hosted or coordinated 89 events worldwide. Of these, 64 were convened in Laxenburg, and 10 events were held in member countries. The events were attended by a total of 1,227 conference participants, with 819 being from member countries.
- **Alumni Association** – IIASA has 4,570 alumni from 99 countries, of whom 25% are actively involved in the institute's scientific activities and many are leaders in academia, government, and the private sector. The Alumni Association coordinates exchange within this network. In 2018, Alumnus William D. Nordhaus received the Nobel Prize in Economic Sciences for his work integrating climate change into long-run macroeconomic analysis, which he started at IIASA.
- **Distinguished Visiting Fellows** – In 2018, Heide Hackmann, Helga Kromp-Kolb, and Dame Lesley Anne Glover became IIASA Distinguished Visiting Fellows.

Strategic partnerships and collaborations

In 2018, IIASA signed a strategic partnership with the Organization for Economic Cooperation and Development (OECD) during a visit of the OECD Secretary-General Angel Gurría to IIASA in March. Building on a strong history of mutual collaboration a joint task force on systems thinking, anticipation, and resilience has been established, involving all IIASA research programs as well as almost all directorates of OECD. The main aim of the partnership is to combine the policy and action expertise of the OECD with the scientific and analytical excellence of IIASA to promote the use of systems thinking in policymaking through the development of methods and tools.

In addition, IIASA has signed a Memoranda of Understanding with the German University of Koblenz-Landau with the objective of advancing systems thinking in education, research, and capacity development. Also in 2018, IIASA joined the Global Energy Interconnection Development and Cooperation Organization (GEIDCO), which connects the world's most important stakeholders in the energy sector.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Research partners 819
Conference participants and visitors
Alumni
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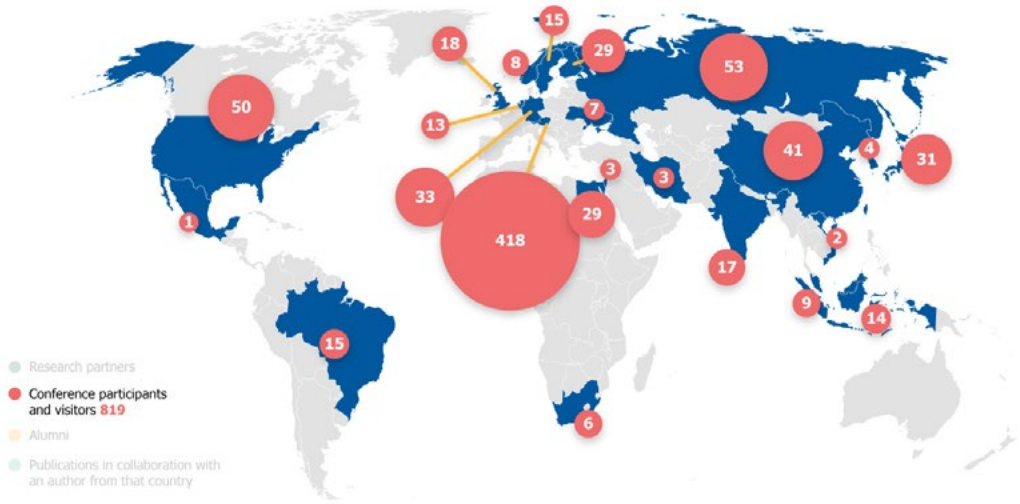
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Conference participants and visitors 819
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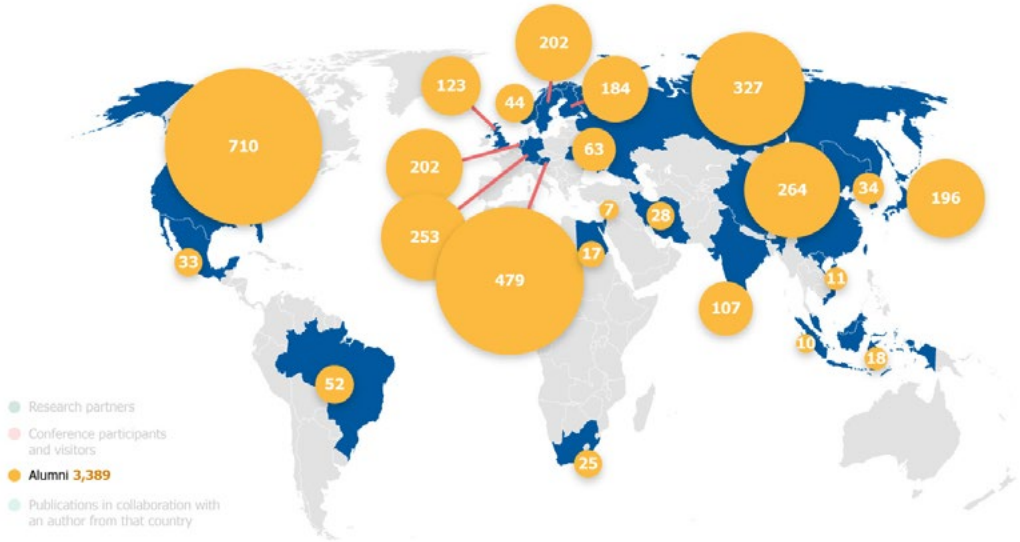
Publications in collaboration with an author from that country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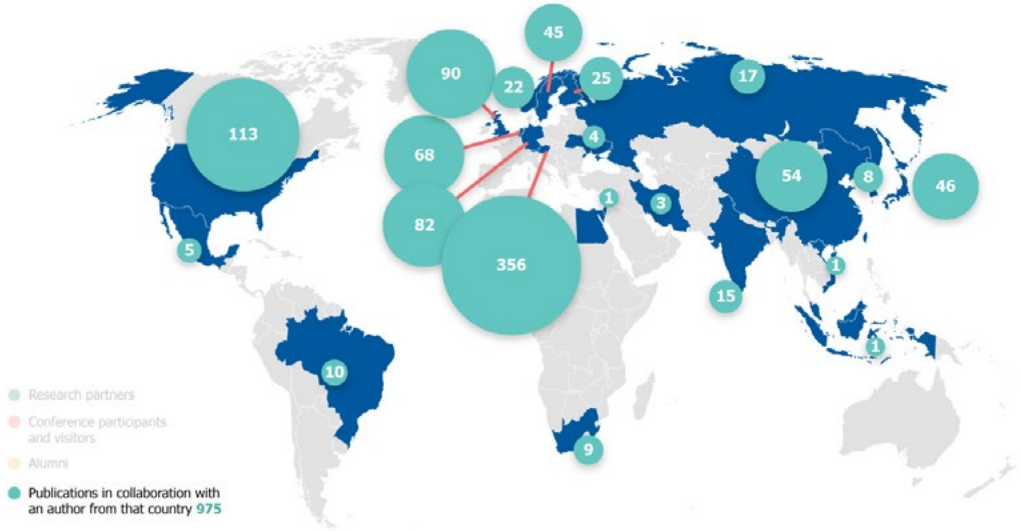
Research partners
Conference participants and visitors
Alumni 3,389
Publications in collaboration with an author from that country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Research partners
Conference participants and visitors
Alumni
Publications in collaboration with an author from that country 975

Governance

IIASA is governed by a Council comprised of one permanent representative from each National Member Organization. Regulations concerning the institute's objectives, conditions of membership, internal structure, and the roles and responsibilities of the Council are outlined in the institutional Charter.

IIASA Strategic Plan **2011-2020**

IIASA Research Plan **2016-2020**

National Member Organizations

Each IIASA member country designates a National Member Organization (NMO) to represent the nation's scholarly community, and act as a bridge between their research and policy communities and the institute. There are three types of NMOs namely, national academies, government research funding agencies, and autonomous organizations or committees. Each member country fulfills two main roles, which it enacts through its NMO. The first of these involves the governance of the institute through its representative council member for IIASA, while the second requires the NMO to act as a link between IIASA and national stakeholders.

Membership of IIASA

The IIASA Charter stipulates that membership of the institute is open to one professional institution from any country as long as it represents the relevant scholarly community of that country, subscribes to the IIASA Charter, and meets the financial obligations of membership. The IIASA Council votes on each country's application to join the institute and on whether to discontinue a country's membership.

In June 2018, Council thanked the Netherlands, represented by the Netherlands Organization for Scientific Research (NWO), for its contribution to IIASA as a member since 1977 and regrettably noted the NWO's decision to discontinue its membership in 2019. Council also recognized the expiration of the observer membership status of Pakistan, represented by the Pakistan Academy of Sciences, and thanked them for their contribution to IIASA as a member since 2007, accepting with regret, that the Academy's membership of IIASA had ended.

IIASA National Member Organizations and Council members

On 31 December 2018, IIASA had 23 member countries (1 observer) represented by the following National Member Organizations:

AUSTRIA The Austrian Academy of Sciences (ÖAW)
Council Member: Professor Dr. Gerhard Glatzel

BRAZIL The Brazilian Federal Agency for Support and Evaluation of Graduate Education (CAPES)
Council Member: Professor Dr. Concepta (Connie) McManus Pimentel

CHINA National Natural Science Foundation of China (NSFC)
Council Member: Professor Dr. Xincheng Xie

EGYPT Academy of Scientific Research and Technology (ASRT)
Council Member: Professor Dr. 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 (Observer) Technology Information, Forecasting, and Assessment Council (TIFAC)
Council Member: Mr. Sanjay Singh

INDONESIA Indonesian National Committee for IIASA
Council Member: Professor Dr. Kuntoro Mangkusubroto

IRAN Iran National Science Foundation (INSF)
Council Member: Professor Dr. Nosratollah Zargham

ISRAEL The Israel Committee for IIASA
Council Member: Professor Dr. Moti Herskowitz

JAPAN The Japan Committee for IIASA
Council Member: Professor Dr. Kazu Takemoto

KOREA, REPUBLIC OF National Research Foundation of Korea (NRF)
Council Member: Dr. Jung-Hye Roe

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 The 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

RUSSIA Russian Academy of Sciences (RAS)
Council Member: Academician Professor Dr. 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 The Ukrainian Academy of Sciences
Council Member: Academician Professor Dr. Anatoly G. Zagorodny

UNITED KINGDOM Research Councils of the UK
Council Member: Professor Dr. Duncan Wingham

UNITED STATES OF AMERICA The National Academy of Sciences (NAS)
Council Member: Professor Dr. Michael Clegg

VIETNAM Vietnam Academy of Science and Technology (VAST)
Council Member: Professor Dr. Ninh Khac Ban

The IIASA Council

Council Committee Membership

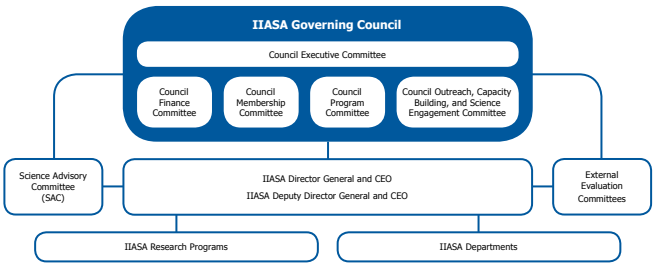
As the governing body of the institute, the IIASA Council is composed of one permanent representative from each NMO. The Council meets twice a year, in June and November. The Charter and subsequent resolutions of Council document the role of Council, its processes, and decisions.

The Council is responsible for determining financial and managerial policies and subject areas for IIASA research, as well as ensuring that IIASA activities are in line with institutional objectives, the provisions of the Charter, and the interests of NMOs.

The Council elects a chair and two vice chairs who act as officers of the Council. Michael Clegg (United States) has been the council chair since September 2017. Alexei Gvishiani (Russia) held the position of council vice chair since 2014, but stepped down at the end of 2018. He will be replaced by Lea Kauppi (Finland) as of January 2019. Gansen Pillay (South Africa) has been council vice chair since January 2018.

The Council appoints the director general and the deputy director general who, as the chief executive officers of the institute, are responsible for implementing the research program and managing the day-to-day operations. In 2018, the Council appointed Albert van Jaarsveld as the 11th director general of IIASA. Van Jaarsveld, a South African citizen, was the vice-chancellor and principal of the University of KwaZulu-Natal in South Africa, and president and CEO of the South African National Research Foundation prior to joining the institute.

IIASA Governance and Decision Making Structure and its External Advisory Bodies



The IIASA Council exercises its oversight responsibilities through a committee structure comprising an Executive Committee, a Finance Committee, a Membership Committee, a Program Committee, and an Outreach and Capacity Building Committee. Starting in January 2018, membership of these committees was agreed for a new three-year period. In addition, an external Science Advisory Committee and external evaluation committees provide specialized input to Council.

Evaluation and quality control

Science Advisory Committee

The IIASA Council oversees an array of activities that support its responsibility to offer guidance and assure the quality and relevance of IIASA research. It serves as a critical element in assuring NMOs of the value of the work done by the institute in return for their contributions.

In 2017, the Council commissioned an institutional review to provide an independent and comprehensive evaluation of the institute. Following the delivery of the report the Council established a task force to develop an implementation plan for the recommendations of the IIASA review.

At the end of 2017, Khotso Mokhele and Melody Mentz (both from South Africa) were respectively appointed as chair and secretary of the task force, which in addition comprised three members representing IIASA governance structures, four external experts, and four members from within IIASA.

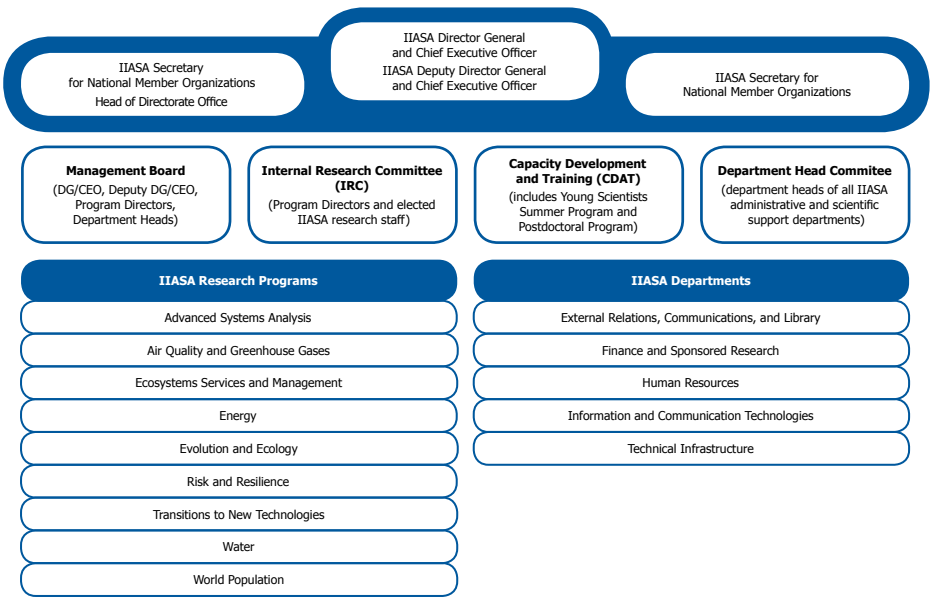
The ultimate purpose of the task force was to facilitate an open and transparent process to achieve consensus on the future of IIASA, including its vision, mission, organizational structure, and governance. The task force developed an implementation plan and presented its final report to the IIASA Council in November 2018.

Another component of research oversight is the IIASA Science Advisory Committee (SAC). The SAC, established by the IIASA Council in 2002, comprises 14 international experts in fields relevant to IIASA research and its science to policy portfolio. The SAC has an academically and geographically diverse membership—based on nominations from NMOs and IIASA—and includes experts in the main areas of the institute's research. In 2018, the SAC continued to provide independent, expert advice to the IIASA Council and directorate to ensure that the institute's work continues to meet the highest scientific standards and remains relevant to policymakers.

IIASA Management

IIASA is currently structured into nine research programs and five departments that support the institute's scientific activities. The director general and his deputy are supported by a Directorate Office, which is also in charge of managing exploratory and special projects. On 1 October Albert van Jaarsveld commenced his appointment as director general and chief executive officer replacing Pavel Kabat who left IIASA at the end of August. For the month of September Nebojsa Nakicenovic was acting director, and Markus Amann acting deputy director of the institute.

IIASA Internal Organization Structure



Compliance

IIASA attributes great importance to compliance with applicable laws, policies, and procedures to ensure that its activities are in line with its objectives, the provisions of its Charter, and the interests of its member organizations.

Health, safety, and wellbeing

IIASA complies with the Luxembourg Declaration on Workplace Health Promotion and the Austrian Employee Safety Law (Arbeitnehmer Innenschutzgesetz). These laws stipulate that an occupational health doctor must be employed by the institute. IIASA has worked with a general practitioner qualified in occupational medicine since 1997, and in 2017, the institute also 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 and office set up
- 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 2018, one notable incident was 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 Austrian legal framework regarding health and safety in the workplace (i.e., ArbeitnehmerInnenschutzgesetz, Mutterschutzgesetz, Bildschirmverordnung).

In 2018, an external safety services company provided a specialist to support the institute's doctor and psychologist in evaluating and documenting the implementation of the laws and guidelines listed above and come up with strategies to improve employee health at work with a specific focus on workplace safety (Arbeitsplatzsicherheit).

Data management and archive policies

The IIASA rules laid out in its policies on Good Scientific Practice and Conflict of Interest, constitute the institute's current data archiving standard. To comply with the requirements of research funders and other collaborators, IIASA policy stipulates that all primary research data must be retained for a minimum of 10 years, thus ensuring the reproducibility of findings and results. In addition, model-based work, model specifications, and methods of analysis have to be sufficiently documented, ideally in a peer-reviewed publication or its official supplement.

Financial policies and procedures

The Finance Committee of the Council supervises the institute's accounting and auditing activities, annual payments of National Member Organization contributions, the 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 on an annual basis. IIASA's statutory financial statements are audited by BDO Austria.

In addition, some external funders require that the projects they contribute to are 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, four major second-level audits on twelve projects were carried out in 2009, 2011, 2015, and 2017 respectively. All of these were successfully concluded.

At IIASA, financial policies and procedures are in place for:

- Sponsored research and budgeting for proposals (sections 4.4.7 and 4.4.8 of the IIASA Operating Procedures and Policies)
- Procurement, business travel, organizing conferences, and visits from external collaborators and stakeholders (section 4.4 of the IIASA Operating Procedures and Policies)
- A budget planning and oversight process (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.

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 research activities at IIASA is used to bring about the widest possible benefits. This includes that the institute gains financially from any commercial exploitation of patents resulting from the use of its resources, and that favorable terms are applied in granting licenses to organizations and citizens of National Member Organization countries. The Software Policy defines and protects the intellectual property rights for software developed by IIASA staff, and outlines the processes for commercialization, licensing, and distribution.

The IIASA Copyright Policy takes the practices of international journals and publishers into consideration and aims to facilitate the widest possible dissemination of IIASA results. In 2018, a revised version of the institute's Scientific Publications and Copyright Policies was drafted taking into account the latest developments in academic publishing, open access publishing, and the use of creative commons licenses to expand the sharing and uptake of IIASA research.

Information technology and data security

During 2018, the Information and Communications Technologies (ICT) Department improved online security through a full replacement of the network firewalls and the implementation of specialized security systems to protect internet facing IIASA applications and tools.

In addition to managing the IIASA mobile telephone program that provides nearly 150 staff with mobile telephones and access to worldwide data roaming capabilities, the ICT Department also modernized the office telephone system with a new Voice-over-IP system in 2018.

Legal compliance

IIASA is legally registered as a "Verein" (Association) in Austria with registration number (ZVR-Nr 524808900) and is subject to the laws and jurisdiction of its host country, Austria. These include all laws that typically affect 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
- 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, and the EU General Data Protection Regulation (GDPR) which came into effect on 25 May 2018.

Infrastructure development

In 2018, the host country carried out a major retrofitting of the Schloss to bring the building up to date with fire safety regulations. This included the installation of fire doors, smoke exhausts, alarm systems, and emergency lighting. In addition, an audit was undertaken with the aim of receiving the "Klimabündnis" (Climate Alliance) label granted by the state of Lower Austria.

Environmental performance

The 2018 IIASA staff association (STAC 2018) formed an Environment Committee with the aim to improve the institute's environmental performance. The committee introduced an initiative comprised of representatives from IIASA programs and departments to act as Sustainability Champions.

Over the course of 2018 the Environment Committee and Sustainability Champions produced "green event guidelines" to help event organizers make IIASA events more sustainable. Implemented initiatives include the introduction of reusable tableware that are now used at all IIASA STAC events instead of single-use plastic equivalents. The committee also reviewed personal computer (PC) power saving policies and ran a campaign to reduce power usage. In 2019 a campaign will be launched to target a reduction in printing across the institute.

In order to obtain the eco label "Klimabündnis Betrieb" ("Climate Alliance Enterprise"), a sustainability audit was conducted by the State of Lower Austria and the Climate Alliance Austria. The audit will set internal sustainability targets to be monitored over the next five years, while the eco label will publicly show the institute's commitment to the goals of the climate and sustainability initiative.

In May 2018, 65 IIASA staff members participated in the annual Austrian Bike to Work month, which aims to encourage more sustainable commuting options. Together the IIASA teams rode more than 12,000 kilometers.

A number of initiatives are already planned for 2019 including, accounting of travel-related emissions, sustainable travel policies, and revisiting climate-friendly menus in the IIASA restaurant. Other measures include encouraging paperless management systems through paperless pay slips, expense reimbursements and timesheets, sustainable procurement and catering policies, and reviewing waste and recycling policies.

Data protection and privacy

IIASA is the controller and processor of personal data concerning both its staff and other individuals associated with the institute. The institute periodically sends bulk mails to some of its contacts for a variety of reasons, ranging from asking them to attend an event, to updating them on IIASA's latest research and activities.

In light of the above, the institute is obligated to follow the provisions of Austrian Data Protection Law. As a member of the European Union, Austria must also comply with the EU General Data Protection Regulation (GDPR), which came into effect on 25 May 2018.

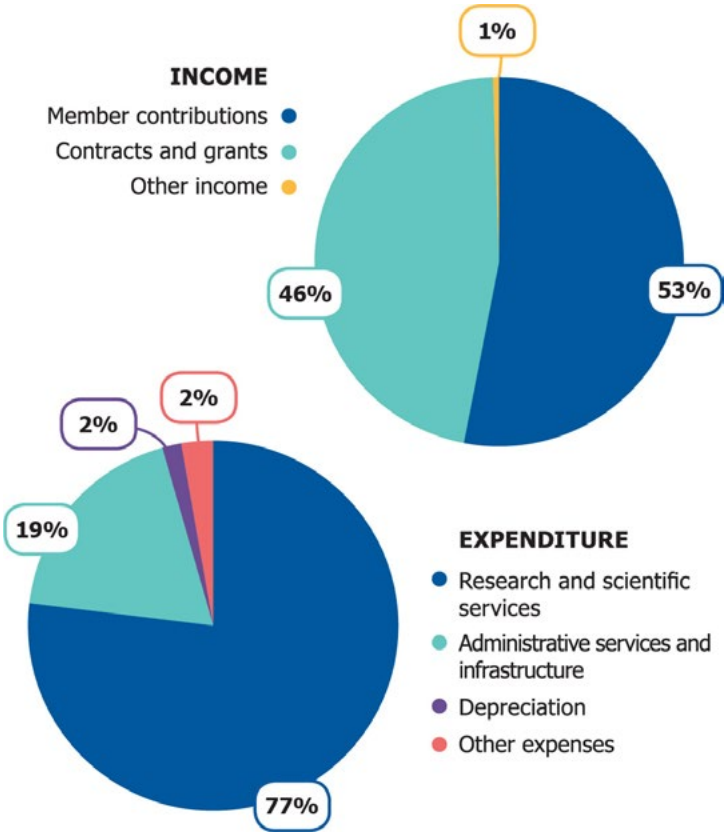
In 2018, IIASA appointed a Data Protection Officer to oversee related issues and work towards compliance of all data protection regulations. The Data Protection Officer provides information on the new regulations to staff and is responsible for answering any queries related to data protection.

Many processes were updated in 2018, including the registration of visitors and conference participants to ensure that they are aware of how their data is stored and used. For subscribers to IIASA publications, evidence was obtained of their subscription preferences and consent to be contacted. The access rights in the management information system were reviewed and updated. In addition, IIASA signed data processing agreements with third parties where necessary to cover any transfer of data. Development of a Data Processing Register was initiated, which will be populated throughout 2019.

Financials

The institute's annual budget in 2018 was €22.7 million, of which over 53% was from research funding agencies in member countries in Africa, the Americas, Asia, and Europe. These diverse sources of income enable IIASA to perform research that is truly independent. The institute receives additional funding from contracts, grants, and donations from governments, international organizations, academia, businesses, and individuals. Between 2017 and 2018 this additional funding increased by 25% from €8.4 million to €10.5 million.

2018 was a year of planned financial stabilization for IIASA following a challenging year in 2017. Total income grew by 7% from €21.1 million in 2017 to €22.7 million in 2018, with total expenditure declining marginally from €23.0 million to €22.6 million. At €17.4 million, almost 80% of the institute's total spending in 2018 was on research and scientific services, while it was also possible to consolidate spending on administration services and infrastructure. IIASA operated within its financial means in 2018, with the positive change in net assets serving to strengthen fiscal reserves.



	31-DEC-18 (€)	31-DEC-17
INCOME		
Membership contributions (I)	12,040,500	12,317,700
Contracts and grants (II)	10,513,481	8,395,675
Other income	97,998	423,441
TOTAL INCOME	22,651,979	21,136,816
EXPENDITURES		
Research and scientific services	17,396,024	17,365,998
Administrative services and infrastructure	4,219,167	4,396,288
Depreciation	374,593	541,280
Other expenses	567,579	323,914
Provision for membership contributions	0	350,000
TOTAL EXPENDITURE	22,557,364	22,977,480
Change in net assets	94,616	-1,840,664

	31-DEC-18 (€)	31-DEC-17
NON-CURRENT ASSETS		
Property, plant, and equipment	679,923	906,787
TOTAL NON-CURRENT ASSETS	679,923	906,787
CURRENT ASSETS		
Inventories	23,810	25,340
Work in progress	2,699,787	1,453,230
Receivables and prepayments	4,408,747	4,793,116
Cash and cash equivalents	8,288,378	9,152,759
TOTAL CURRENT ASSETS	15,420,722	15,424,445
TOTAL ASSETS	16,100,645	16,331,232

NET ASSETS		
Restricted funds	687,600	914,464
Unrestricted funds	5,907,857	5,586,378
TOTAL NET ASSETS	6,595,457	6,500,842
NON-CURRENT LIABILITIES		
Provisions	2,456,374	2,493,895
TOTAL NON-CURRENT LIABILITIES	2,456,374	2,493,895
CURRENT LIABILITIES		
Prepayments	4,174,705	4,622,116
Provisions	1,605,551	1,506,118
Other liabilities	1,268,558	1,208,260
TOTAL CURRENT LIABILITIES	7,048,814	7,336,494
TOTAL LIABILITIES	9,505,188	9,830,389
TOTAL LIABILITIES & NET ASSETS	16,100,645	16,331,231

Research funding agencies

In 2018 IIASA membership contributions were provided by the following agencies:

- 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
- Ministry of Foreign Affairs, Indonesia
- Ministry of Finance, Japan
- National Research Foundation of Korea (NRF)
- 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)
- Russian Academy of Sciences (RAS
- National Research Foundation (NRF), South Africa
- The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (FORMAS)
- National Academy of Sciences of Ukraine (NASU)
- 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)
- Ministry of Science and Culture, Israel

Donations

The YSSP Fund provides funds for a scholarship that is awarded to promising young researchers without National Member Organization support, often from developing countries, to participate in the IIASA three-month Young Scientists Summer Program (YSSP). Generous donations from IIASA supporters enabled seven exceptional young scientists to participate in the 2018 YSSP.

The purpose of the Women in Science Fund is to provide a platform of financial support to IIASA women connected to science at all career levels. Conceived by the IIASA Women in Science Club, the fund offers different avenues of support and relies solely on donations to fulfill its mission.

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.

A donation to the Howard Raiffa Fellows Program in Decision Science preserves the legacy of the first IIASA director and brings distinguished scientists in this field to IIASA to work on the global problems addressed by the institute's research programs.

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 for their generosity in 2018 and is grateful for their commitment and belief in the mission of the institute.

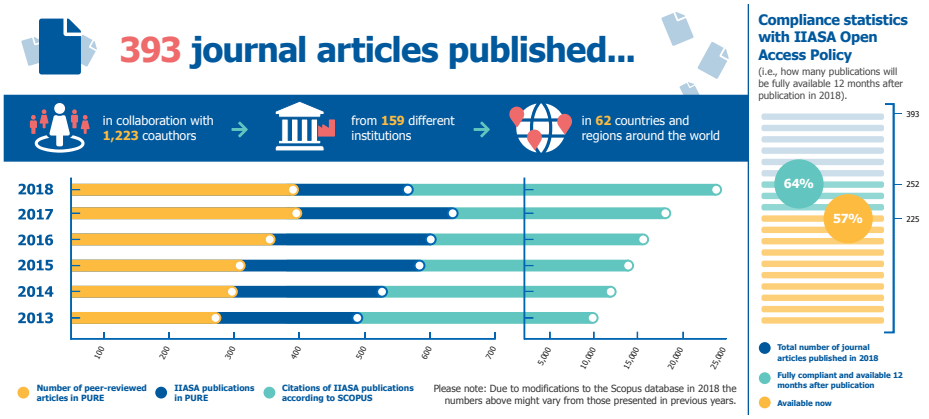
Publications and open access

2018 publications

In 2018 there were **564 IIASA publications**, of which **393 were peer-reviewed journal articles**. These articles were written in collaboration with over **1,223 coauthors from 159 institutions in 62 countries and regions.**

The IIASA scientific publications and copyright policy sets forth the principles governing the various types of publications used by the institute to communicate its research results to outside audiences and aims to facilitate the widest possible dissemination of the institute's work. The policy was reviewed in 2018 to also cover copyright and funder acknowledgments and is pending internal approvals.

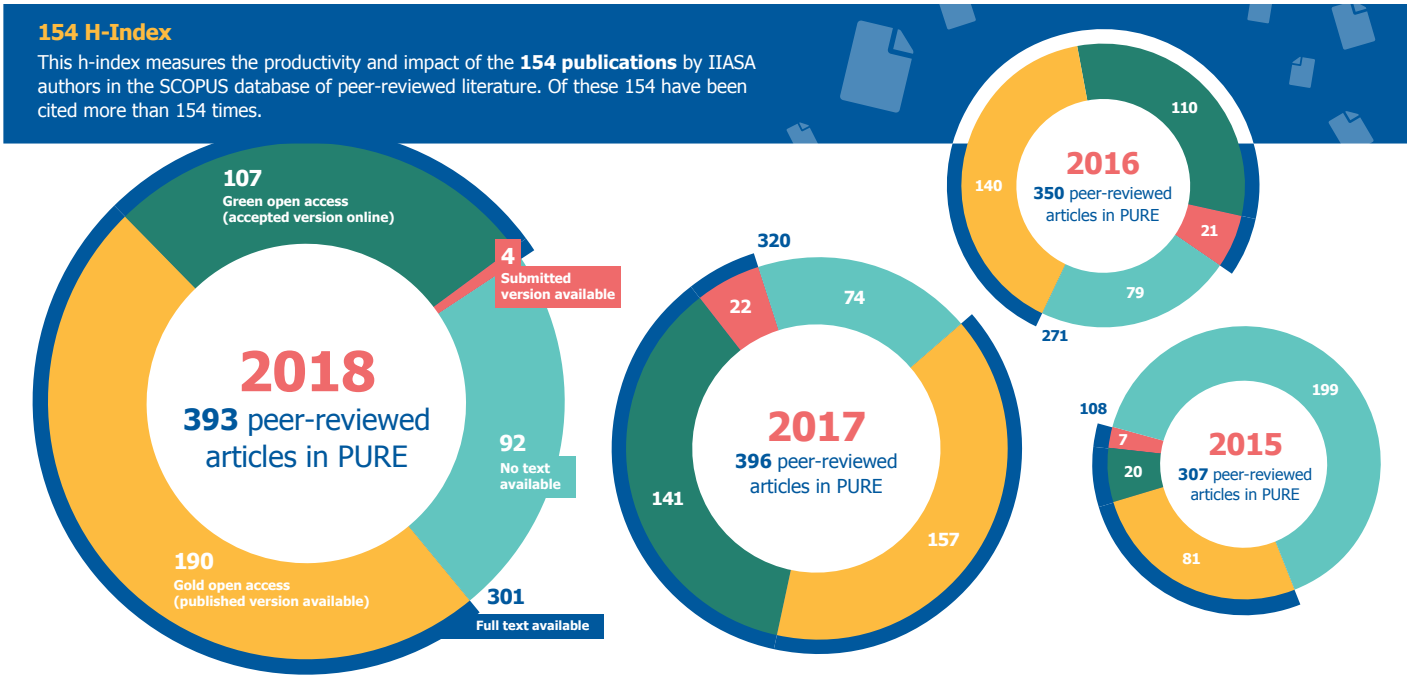
The open access to publications policy requires that all IIASA authors deposit a complete version of their peer-reviewed research articles in the IIASA institutional repository (PURE) to ensure that it is freely accessible within a year of the online publication date. This can either be the published version of the paper (known as gold open access), or the accepted version of the paper (known as green open access).



Of the 393 journal articles published in 2018, 225 have a publicly available full text version in PURE. A total of 76 are currently under embargo and 92 entries have no paper attached. As of January 2019, 64% of articles published in 2018 will be fully available after twelve months and will be compliant with the open access policy. In 2018, there were 339,156 downloads from PURE, compared to 252,129 the previous year.

IIASA has publishing agreements with major publishers like Springer, Wiley, Taylor and Francis, and MDPI which allow for a discount on article processing charges or enable open access publishing without additional costs for authors affiliated with IIASA.

These agreements were all renewed in 2018 and enabled the publication of over 60 open access articles. Because IIASA encourages its researchers to publish their research in journal articles or books that are available free of charge to all users (gold open access), it has established a fund for covering open access fees. In 2018, this fund was made available to researchers to partially cover publication costs if no other grant is available. This facilitated the publication of 31 articles through gold open access.



Open access to data

In November 2018 the IIASA Council approved a policy on open access to data. This policy encourages publishing research data produced by IIASA researchers while adhering to the requirements of member countries and funding bodies. To fulfil the policy's requirements an institutional research data repository, DARE, was developed during 2018 and was launched in February 2019. Deposited data will receive a persistent citable identification URL and will remain openly accessible and stored for a minimum of 10 years according to IIASA policy or as long as is mandated by the funding body. This will help researchers with the reproducibility, traceability, and validation of critical research produced by IIASA.

National Member Organizations:

On 31 December 2018, IIASA had 23 member countries (1 observer) represented by the following National Member Organizations:

AUSTRIA	The Austrian Academy of Sciences (ÖAW)
BRAZIL	The Brazilian Federal Agency for Support and Evaluation of Graduate Education (CAPES)
CHINA	National Natural Science Foundation of China (NSFC)
EGYPT	Academy of Scientific Research and Technology (ASRT)
FINLAND	The Finnish Committee for IIASA
GERMANY	Association for the Advancement of IIASA
INDIA *(Observer)*	Technology Information, Forecasting and Assessment Council (TIFAC)
INDONESIA	Indonesian National Committee for IIASA
IRAN	Iran National Science Foundation (INSF)
ISRAEL	The Israel Committee for IIASA
JAPAN	The Japan Committee for IIASA
KOREA, REPUBLIC OF	National Research Foundation of Korea (NRF)
MALAYSIA	Academy of Sciences Malaysia (ASM)
MEXICO	Mexican National Committee for IIASA
NETHERLANDS	The Netherlands Organization for Scientific Research (NWO)
NORWAY	The Research Council of Norway (RCN)
RUSSIA	Russian Academy of Sciences (RAS)
SOUTH AFRICA	National Research Foundation (NRF)
SWEDEN	The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (FORMAS)
UKRAINE	The Ukrainian Academy of Sciences
UNITED KINGDOM	Research Councils of the UK
USA	The National Academy of Sciences (NAS)
VIETNAM	Vietnam Academy of Science and Technology (VAST)

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