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

options

winter 2010/2011

Energy & climate change

New perspectives

Detlof von Winterfeldt
Director, IIASA

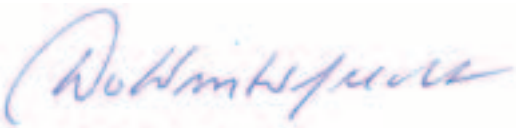
New perspectives

This issue of *Options* is the first in a series devoted to our new 2011–2015 research themes focusing on complex global problem areas—Energy and Climate Change; Food and Water; and Poverty and Equity. The *Options* series will include articles and information on IIASA's new research paths and the application of our work to issues of human and environmental wellbeing. It will also survey the methodologies we are developing and using to address these challenges.

Ever since IIASA first published *Carbon Dioxide: Climate and Society* in 1978 and *Energy in a Finite World* in 1981, the research topics of energy and climate change have always been closely linked at our Institute. Energy production and consumption, including heating, electricity and transportation, contribute over 80 percent to all greenhouse gas emissions in the world, making a combined study of them essential. There are also multiple benefits in pooling the resources of scientists looking at problems from different perspectives. This has always been a great strength of IIASA, and by formalizing the links, we believe that our energy and climate change research endeavors will be even more fruitful.

The study of energy and climate change also has close links with the other global problem areas being studied at IIASA. For example, providing access to clean energy to the poorest in the world will increase both their health and wellbeing; and we need to better understand the disproportionate impacts of climate change on the least developed countries. Integrated assessments that link the three global problem areas of IIASA's research plan can deliver insights and suggest solutions to the important policy issues on national and international agendas. With a large number of our scientists currently carrying out high-level research for the IPCC Fifth Assessment Report and the IIASA-hosted Global Energy Assessment, I can safely say that our researchers are currently at the top of their game.

Options has always been a source of useful and accessible information to the science and policy community and I hope that you will enjoy this latest issue on energy and climate change. You can read about how IIASA scientists are describing the multiple benefits of clean energy (page 12), the exciting opportunities offered by using bioenergy combined with carbon capture to reduce atmospheric carbon (page 16), and our leadership over uncertainty issues in greenhouse gas inventories (page 19). I look forward to receiving your feedback. ■



About IIASA

IIASA is an international scientific institute that conducts policy-relevant research into problems too large or complex to be solved by a single country or academic discipline.

IIASA's scientists research
- energy and climate change;
- food and water;
- poverty and equity;
- drivers of global transformations;
- policy and governance; and
- advanced systems analyses.

IIASA produces
- data, models, and research tools;
- refereed scientific literature; and
- policy-relevant information.

IIASA helps
- countries make better-informed policy;
- develop international research networks; and
- support the next generation of scientists.

IIASA is funded and supported by scientific institutions and organizations in the following countries:

Austria, China, Egypt, Finland, Germany, India, Japan, Netherlands, Norway, Pakistan, Poland, Republic of Korea, Russia, South Africa, Sweden, Ukraine, United States of America.

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IIASA

About *Options*

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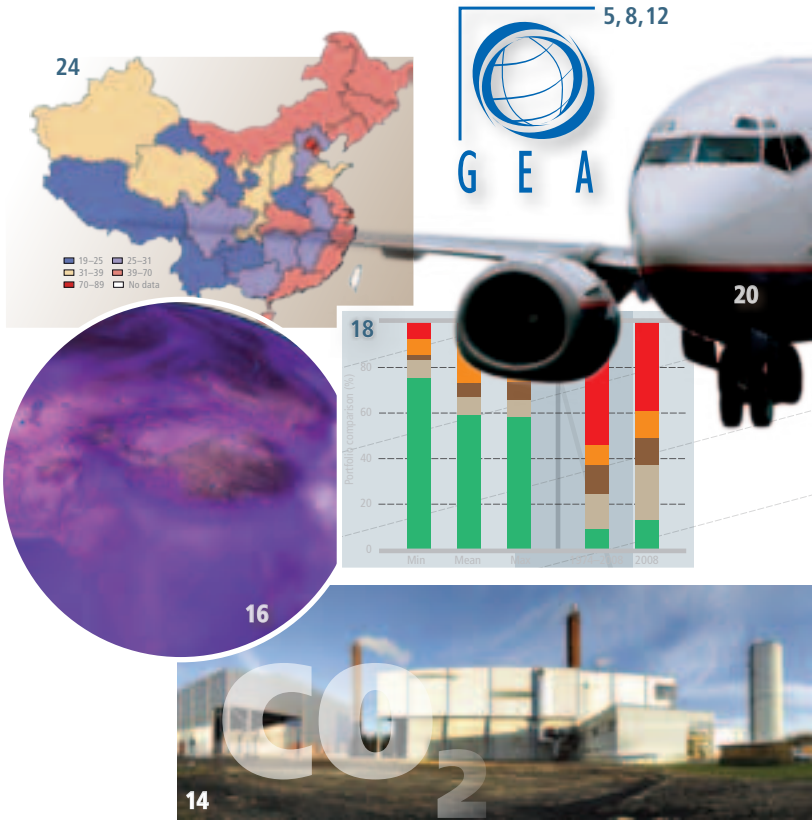
contents



IIASA & UNITED NATIONS

Consolidating ties: United Nations Secretary-General visits IIASA

The visit of United Nations Secretary-General Ban Ki-moon and Mrs. Ban to IIASA on 2 September was the first-ever visit by a United Nations Secretary-General to the Institute. Also accompanying the Secretary-General were the Foreign Minister of Austria, Dr. Michael Spindelegger, the Governor of Lower Austria, Dr. Erwin Pröll, and the newly appointed Executive Director of the United Nations Office on Drugs and Crime and Director-General of the United Nations Office in Vienna, Mr. Yury Fedotov.

While at IIASA the Secretary-General discussed the main global problem areas that form the basis of IIASA's new strategic research priorities—food and water, energy and climate change, and poverty and equity—and how these support the Secretary-General's seven "Priorities for Action" for the United Nations.

IIASA has significant and ongoing interactions with the UN, having provided briefings to the Secretary-General in New York, most recently on energy and climate change by IIASA Director Detlof von Winterfeldt and IIASA Deputy Director Nebojsa Nakicenovic. In addition Nakicenovic is a member of the Secretary-General's Advisory Group on Energy and Climate Change (see *Options*, Summer 2010); IIASA and GEA advise UN Energy, which coordinates the energy work in the United Nations System; and IIASA scientists collaborate with many other United Nations Organizations. ■

UNITED NATIONS SECRETARY-GENERAL WITH IIASA STAFF
UN Secretary-General Ban Ki-moon with Mrs. Ban, the Foreign Minister of Austria Dr. Michael Spindelegger, the Governor of Lower Austria Dr. Erwin Pröll, the Executive Director of the UN Office on Drugs Mr. Yury Fedotov, the Mayor of Laxenburg Mr. Robert Dienst, and members of IIASA's staff outside the Institute in Laxenburg, Austria

WORLD ENERGY FORUM

"The Missing MDG"

"Energy is the missing Millennium Development Goal," said IIASA's Deputy Director Nebojsa Nakicenovic at the High-Level Conference on Energy at the World Energy Forum held at UN Headquarters, New York, on 17 September.

The Conference Declaration endorsed the importance of energy in making progress to meeting the Millennium Development Goals (MDGs). It also recognized the vital significance of energy for sustainable development and the impact of sustainable energy use on the lives of hundreds of millions of people. The importance of the United Nations in harmonizing and coordinating the efforts of the main agencies involved in energy was also highlighted. ■

www.theworldenergy.org/beta/node/321

ENERGY CONFERENCE

Upping the energy stakes: Access and efficiency

In 2009, the highly successful Vienna Energy Conference, organized by UNIDO, the Austrian Government, and IIASA, set the agenda for an integrated energy agenda beyond 2020. The 2011 Vienna Energy Conference will be taking an enormous substantive step forward with its theme, just announced, of "Energy for All—Time for Action."

The Conference, scheduled to take place on 20–22 June 2011, will bring together heads of state, policymakers, experts, civil society, and the private sector to discuss how to achieve universal access to modern energy, how to achieve major improvements in energy efficiencies, and how to move from declarations of intent to tangible action on the ground. It is expected to attract over 1,000 high-level energy experts.

Delegates to the Conference, organized by UNIDO, the Austrian Government, and IIASA, will first forge agreement on a common understanding of the term "energy access." They are then expected to develop a strategy to ensure the realization—by 2030—of both universal access to modern energy services and increased energy in efficiency through a 40 percent reduction in global energy intensity (the ratio of energy to economic activities).

Key national and regional actions on energy access and energy efficiency will also be set out and prioritized. See the Web site for the most up-to-date information and how to register. ■

www.viennaenergyconference.org

NATURAL DISASTERS

Urgent action to mitigate and adapt

A special issue of *Mitigation and Adaptation Strategies for Global Change*, co-edited by IIASA's Reinhard Mechler, shows mounting evidence of a significant climate-change signal in natural disaster events (e.g., extreme precipitation at mid and high latitudes, extreme floods and droughts) with Europe being increasingly concerned about the adverse impacts of climate variability and climate change. The special issue reviews impacts, risks, and adaptation to extreme weather events in Europe under global and climate change. The studies find that postponing any action until robust and less uncertain information has been gathered, although not vanished completely from the debate, increasingly leads to an important loss of opportunity, irrespective of future changes.

Most of the multi-disciplinary material of the special issue originates from work carried out by an international group of researchers for the ADAM (Adaptation and Mitigation Strategies) Integrated Project of the 6th Framework Program of the European Union. ■

Kundzewicz ZW, Mechler R (2010). Assessing Adaptation to Extreme Weather Events in Europe. *Mitigation and Adaptation Strategies for Global Change* 15(7).

FINAL PUBLICATION

Global Energy Assessment launch

The Global Energy Assessment (GEA), hosted at IIASA, is to launch the results of its five years of research at the 2011 Vienna Energy Conference on 22 June 2011. The publication, *Global Energy Assessment*, is to be published by Cambridge University Press in May. In 25 detailed and comprehensive chapters it maps the global energy system and develops an action-oriented roadmap to address the major challenges and needed transformational changes on the way to a sustainable energy future. It is intended to be a strong technical and scientific basis for decision making providing an integrated perspective on the multiple co-benefits of these transformational changes. ■

www.globalenergyassessment.org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INVESTMENT STRATEGIES

Decarbonizing in China

China is the world's highest CO_2 emitter, with coal accounting for about 70 percent of total energy consumption. The power industry in China is confronted with major challenges from increasingly strict policies, both national and international, aiming at the reduction of greenhouse gases and atmospheric pollutants.

Carbon capture and storage (CCS) has been emphasized by China as being potentially one of the most important mitigation measures for CO_2. However, problems related to CCS, especially its high cost, are causing great uncertainty with respect to both CCS R&D and more widespread acceptance of the technology.

IIASA researchers carried out a real options analysis of CCS investment strategy in China's power sector. They found that retrofitting existing power plants with CCS can provide substantial benefits in terms of offering higher flexibility in the face of the threat of high, yet uncertain penalties for emitting carbon. A vital role is played by policymakers, however, who have to credibly commit to strict climate policy at an early stage in order to give the right incentives to investors.

Considering the advantages of integrating CCS in more modern integrated gasification combined cycle (IGCC) plants and given the relative advance of Western countries in IGCC, technology transfer could enable China's power industry to implement CCS at a larger scale and more cost-effectively against a backdrop of more stringent future climate policy. ■

Zhou W, Zhu B, Fuss S, Szolgayová J, Fei W (2010). Uncertainty modeling of CCS investment strategy in China's power sector. *Applied Energy* 87(7):2392–2400.

DEMOGRAPHY

Remeasuring aging

Future age-structure changes, such as growth in the number of elderly, decline in the number of young people, and accompanying economic and social costs are of international concern. But as life expectancies increase and people remain healthy longer, measures based solely on fixed chronological ages can be misleading. Many age-specific characteristics have not remained fixed and are not expected to remain constant in the future.

In the 10 September issue of *Science*, authors from IIASA and the Vienna Institute of Demography showed that aging forecasts for all countries based on new measures that account for changes in longevity, as well as new forecasts based on disability status, exhibit a slower pace of aging compared with the conventional ones. Disability-free life expectancies, which describe how many years of life are spent in good health, have been increasing, often as fast as unconditional life expectancies, because of decreases in age-specific disability rates. The authors point to the United States, where the proportion disabled in the 65–74 age group declined from 14.2 percent in 1982 to 8.9 percent in 2004–2005, an important consideration for policymakers assessing potential healthcare costs. ■

Sanderson WC, Scherbov S (2010). Remeasuring Aging. *Science* 329(5997):1287–1288.

NEW IIASA RESEARCH AREA

Energy & climate change

One of the three global problem areas IIASA will focus on this decade

Many of the global challenges that confront us today are the result of greenhouse gas (GHG) emissions and air pollution caused by the continuing use of fossil and other "dirty" fuels. At the regional scale, anthropogenic emissions of GHGs and other radiatively active substances, such as sulfur aerosols and particulate matter, result from energy production, processing, conversion, transport, and end use—all of them key drivers of economic development. At the local scale, with half the world's population lacking access to affordable modern energy services for cooking and more than a quarter without access to electricity, indoor air pollution from the burning of traditional fuels like biomass are a major cause of ill health, particularly in women and children. Clearly, improving human wellbeing across the board without endangering the natural environment will require a careful balancing act to simultaneously take account of both economic and social development needs.

Tackling climate change in conjunction with energy systems is an important entry point for addressing this global problem area. Keeping the global mean temperature change below 2°C above pre-industrial levels will require a peak to be reached in greenhouse gas emissions immediately and a decline toward zero emissions in the second half of the century. The later this occurs, the more so-called "net-negative" emissions will be needed toward the end of the century, which require the deployment of technologies that, for example, capture and store carbon from sustainable energy biomass. Hand in hand with these transformative changes, the decarbonization of energy systems, from global to place-specific levels, must become an accepted development goal, while major global initiatives must be undertaken to achieve universal clean energy access during the next decades.

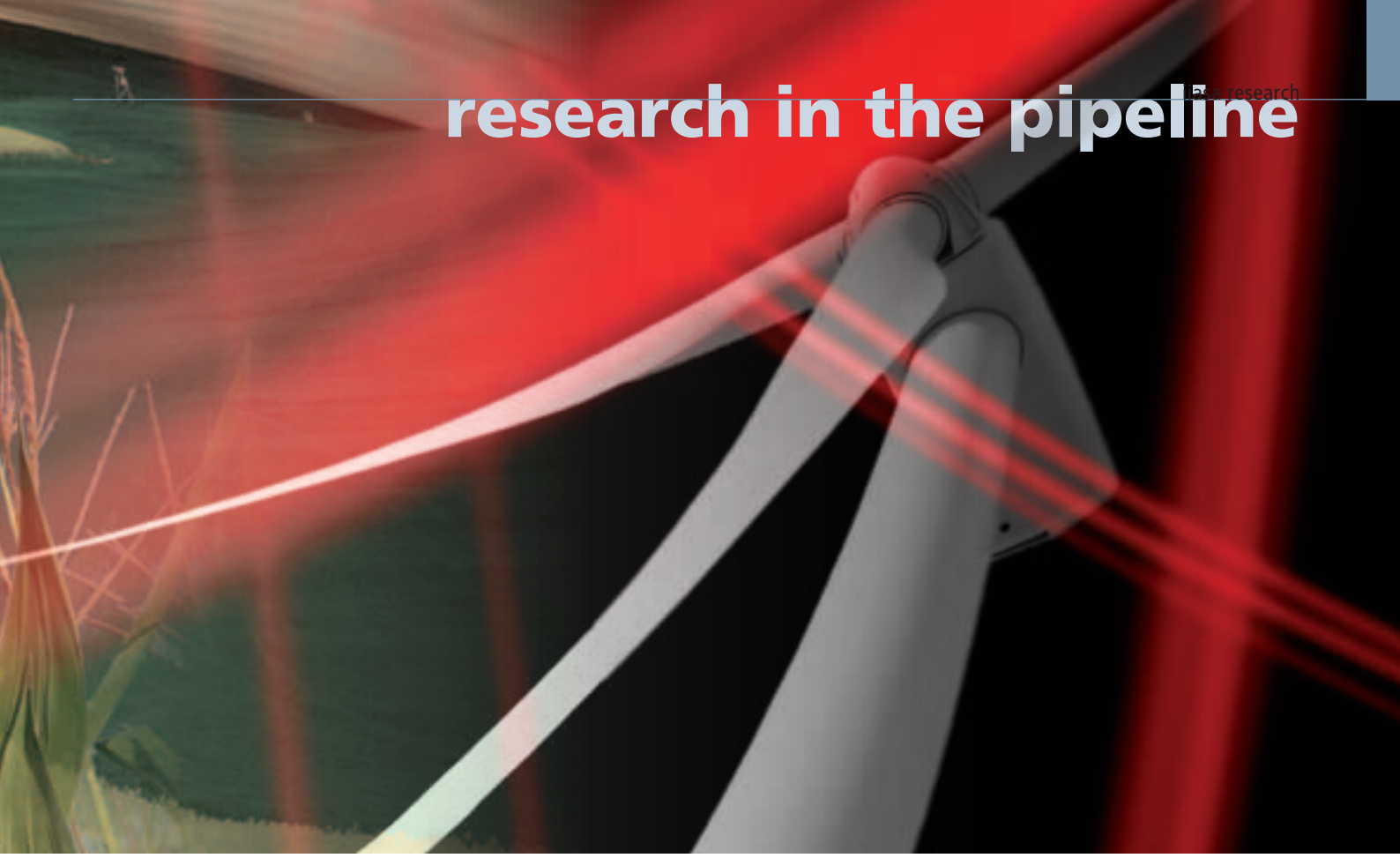
As the world becomes more connected and dependencies increase, further integration of energy systems is needed to help reduce risks to the security of both energy supply and end use, for instance, smart grids that combine centralized and decentralized systems with increasing storage of energy through to end use (e.g., hybrid or electric vehicles). It is estimated that the global private and public energy R&D efforts, which have fallen sharply since the early 1980s, need to increase threefold while the investments should at least double to achieve these goals. Strong governance and institutional support are also needed for implementation, as are new institutional architectures and business models oriented toward the delivery of clean energy services.

The response to these major challenges requires fundamental transformational changes in the energy systems and their integration with strategies for other adaptations to climate change and globalization. During 2011–2015 IIASA's new Energy and Climate Change research area will examine these related issues in four ways:

The recognized need to **transform to a global low-carbon (green) energy system** within the next two decades is the first research theme. Temperature stabilization at 2°C above the preindustrial level, as laid down in the 2010 Copenhagen Accord, and subsequently concurred with by 100+ countries, will guard against catastrophic climate change. Reduction of the carbon intensity of economic activities over the next two decades, and vigorous increases in energy services to promote human development and wellbeing, will support the climate goals. Improvements to energy efficiency would take care of almost half of emissions and energy reductions in the future, and important options such as renewables, fossils fuels + carbon capture and storage, and nuclear energy, would make a significant contribution to reducing the rest. For the first time since the 1980s, energy investment is currently declining, which offers a very real opportunity to stimulate "greener" and more sustainable energy investment. IIASA's role here will be to more closely integrate and extend its existing modeling tools, principally MESSAGE and GAINS, to infer the best and most cost-effective decarbonization options, as well as pinpoint those that have the greatest benefits in human, environmental, and financial/investment terms. The policies required to best implement these options will also be thoroughly examined.

The second main research theme involves **reframing and revitalizing the greenhouse gas reduction debate**. Current international climate policy discussions regarding greenhouse gas emission reductions do not reflect the domestic framing of many countries, where mitigation measures are perceived to be in direct conflict with other policy objectives. Multiple policy priorities will be assessed within an integrated framework using a basket of modeling techniques to help identify synergies and tradeoffs among, for example, climate change, energy access, pollution, energy security and other local development goals, thus providing multiple benefits across all these dimensions and accommodating the views of all parties. Policies that would result in quantifiable improvements to current non-climate related policy priorities,

research in the pipeline



while making positive contributions to mitigation of, and adaptation to, long-term climate change include: resource-efficient production systems, increased energy security and access, improved approaches to coping with extreme events, including the co-benefits for these of pollution control, and ultimately the extension of this work to cover a wider range of aspects important for human welfare.

The third theme covers **investment in energy and R&D** on the supply and demand side, both of which are in need of trillions of dollars of new investment because of aging infrastructure or locked-in technologies. Two generic groups of energy-technology RD&D (Research, Development and Deployment) efforts and investments will be assessed by IIASA. The first is energy efficiency and conservation improvements; the second is the deployment of alternative technologies and systems. These issues are, of course, many and multifaceted. IIASA will consider both issues in the context of accelerating technological change and transformational breakthroughs. The analyses will concentrate on investment decisions in the renewable energy sector and include a combination of modeling approaches combined with an empirical evaluation of the diverse stakeholders' perceptions, objectives, and strategies.

The fourth theme of IIASA's new Energy and Climate Change research area will be **improvement of resource use efficiency** and its potential for GHG mitigation through alternative consumer choices and technological efficiency improvements—an area that is not yet well understood. For instance, in many energy and climate change models, energy demand options are aggregated in ways that do not always enlighten the policymaker. IIASA will look at which policy instruments could change consumer behavior and promote technological efficiency improvements so as to reduce overall resource consumption and GHG emissions without compromising human welfare and wellbeing. Collaborative research involving expertise from IIASA programs in all areas will be undertaken to extend the current modeling tools developed at IIASA to more thoroughly analyze and understand this important sector.

IIASA's approach to researching the four themes has the following underlying aims:

The first is the sheer **breadth of scientific expertise at IIASA** that can be called upon where research areas overlap. This applies not only inside the Energy and Climate Change research area itself, but to interactions with and feedbacks from other research areas (food and water, poverty and equity) and drivers of global transformations (population and technology). The lesson of nearly 40 years of applied systems analysis is that everything in our world is interconnected and that no one research area can or should be viewed in isolation.

The second aim is to build on our **considerable in-house modeling capability** to enhance methodological depth and breadth and also to use creative integrated solutions to advance research into understanding the problems and finding solutions to them—not only that, but also discovering why and how "solutions" may fail.

The third aim is to ensure that all our research is focused, disciplined, and aimed at **applied solutions in the real world**. This will involve gaining a more direct knowledge of policymakers' needs, the choices they need to make now, and their best options for the future to promote human and environmental wellbeing. The deepening of knowledge of the policy community and the particular political and practical issues they face is also an important aim of the overall IIASA research area.

The Global Energy Assessment (GEA) demonstrates the success of the above approach by bringing together around 350 energy analysts from around the world, building on IIASA's and others' modeling expertise, and making significant contributions to ongoing political processes and debates. Indeed, the GEA, which is hosted by IIASA, will help pave the way for many of the aforementioned research themes via its scientific assessment to be published in 2011 at the Vienna Energy Conference (see pages 4 & 5). ■

Further information *Research for a Changing World: IIASA Strategic Plan 2011–2020* at www.iiasa.ac.at/docs/strategic_plan.html

Prof. Detlof von Winterfeldt is IIASA Director and **Prof. Nebojsa Nakicenovic** is IIASA Deputy Director.

GLOBAL ENERGY ASSESSMENT

Scenarios for success in reducing energy poverty

Subsidies for cooking fuel and cheap loans for stoves are the best way to increase people's access to modern forms of energy

In developing countries across the globe, both rural and urban poor cook their food the way humans have for thousands of years—with heat created by fires fueled by wood, dried dung, charcoal, and other forms of biomass. This heavy dependence on inefficient, polluting biomass fuels does damage both to the people and the environment, creating health risks and a kind of "energy poverty" for the individuals, while at the same time causing local soil and forest degradation and substantial releases of carbon into the atmosphere for the planet.

IIASA scientists conducted studies into the impact of this "energy poverty"—which includes both the lack of modern cooking fuels and little or no access to electricity—in India, Africa, South Asia, and Pacific Asia. They found that the dependence on biomass for cooking by both rural and urban poor is not only inefficient in pure energy terms, but has economic and health consequences that keep living standards low.

The solutions for changing cooking fuel use are the same for all of the regions—subsidies for the purchase of cleaner-combusting LPG (liquefied petroleum gas) fuel, combined with low-cost financing to enable the purchase of cook stoves to use the modern fuel. "Subsidies alone on the fuels themselves don't do it," said IIASA environmental and energy economist Shonali Pachauri, a member of the research team. "You have to lower the capital costs. Unless you can give people an easy way to finance the purchase of appliances then you aren't going to change the fuel use. It can be micro-financing or government-backed financing, but it has to make the appliances affordable."

The IIASA research was done in two stages, with the first being a study of how subsidies and financing could change cooking fuel use in India. That study found that biomass is the fuel of choice among poor rural and urban dwellers. The researchers found that, as income levels increase, urban dwellers switch first to kerosene and then to LPG.

Using a model developed at IIASA called MESSAGE-Access that looks at patterns of fuel use and economic strategies for changing those patterns, the researchers found that improving financing for the appliances needed to use LPG, combined with a subsidy for the fuel itself, could mean "the whole population might be prompted to switch to LPG." By doing nothing and letting the current consumption patterns continue, the number of people using traditional biomass would rise over the next decade.

Economic development and the adoption of modern cooking fuels go hand in hand, the study concludes, "and it is hard to imagine improving one without improving the other."

The methodology applied in India was adapted to look at energy poverty in the African and two Asian regions, then expanded to include the consequences of no access to electricity.

As with the India study, the research on cooking fuel use in Africa and South and Pacific Asia found that, "without additional new policies to improve access [to LPG]," the total population in those regions "dependent on solid fuels for cooking will rise from 2.2 billion [in 2005] to 2.3 billion by 2030. Intervention with policies that include subsidies and financing, however, could make a dramatic difference," the scientists said.

According to the study, "A subsidy policy that reduces the price of modern fuels by 20 percent below the existing price level in each region would reduce the numbers of people dependent on solid fuels from 2.25 billion . . . to 1.76 billion." There are other scenarios that


Wikimedia Commons / File:Dung_cooking_fire._Pushkar_India.jpg

look at different combinations of subsidies and financing schemes, and all of them are more effective than fuel subsidies alone.

The most effective is a scenario that combines a subsidy level of 50 percent of fuel costs with 30 percent micro-financing. Such a policy will leave only about 240 million people, largely in Africa, reliant on solid fuels by 2030, the study says, and would cost about US$435 billion over 20 years.

The data gathered on electricity use show that accelerating the pace of electrification in the least developed countries and regions typically requires decisions about electrical grid expansion that are made by national governments or regional bodies. While decisions are often made at the national government level, the cost of grid expansion is typically left to the private utilities, and the result is expansion based purely on economics.

"Thus utilities often select projects that require the least infrastructure investments relative to the level of demand," the study says. The result is that more remote rural regions don't benefit from grid expansion. And when electricity does arrive in an area, there are often connection fees that, like cooking fuel, require subsidies and financing to make the power available to the poorest residents.

Given the high cost and extensive infrastructure that are the hallmark of large-scale electrical systems, Pachauri said the issue involves a different analysis than cooking fuel use. For a host of reasons, from too little capital to bad management, "increasing access to grid electricity in rural sub-Saharan Africa will be difficult," she said. Population density is low, so demand is low, and it simply isn't economical to extend the grid.

The analysis showed that "you have to look at off-grid solutions if you want to bring electricity to many of these areas. There could be mini-grids or, in some cases, renewable sources. If you scale down demand enough you could use solar panels."

While the studies, which are part of IIASA's Energy Program and the Global Energy Assessment, were limited to India and parts of Africa and Asia, Pachauri said the goal is to eventually expand the energy poverty research even further. "We don't include Latin America or China," she said. "We want to look at those countries next." ■

The Global Energy Assessment (GEA)

The energy poverty research conducted by IIASA scientists is part of a much larger Global Energy Assessment initiative, which has the ambitious goal of redefining the global energy policy agenda and helping decision makers face the daunting challenge of providing energy services for sustainable development throughout the world.

IIASA researchers have partnered with over 200 energy analysts worldwide to provide through the GEA a strong technical and scientific basis for decision making by evaluating the social, economic, development, technological, environmental, and security issues linked to energy.

The assessment, begun in 2007, is looking at everything from policies needed to address climate change mitigation to creating sustainable, affordable, and secure energy services as a foundation for economic growth in developing countries. *Global Energy Assessment* will be published by Cambridge University Press in 2011. ■

www.globalenergyassessment.org

Further information Ekholm T, Krey V, Pachauri S, Riahi K (2010). Determinants of household energy consumption in India. *Energy Policy* 38(10):5696–5707.
See also the Global Energy Assessment at www.globalenergyassessment.org

Dr. Shonali Pachuari is a Research Scholar in IIASA's Energy Program.

MESSAGE

Energy plans

More than 80 countries have used an IIASA analytical tool to find cost-effective approaches to meeting future energy needs

Ensuring that a country has an adequate supply of energy isn't easy. Not only do energy planners need to balance energy needs against energy resources, they must also plan over the long term (most power plants are in use for 25 years or more) in such a way that long-lived damage to the environment is not caused. Yet without sufficient energy, a country will struggle to produce goods and provide basic services such as health care or sanitation for its people.

© Alexandre Fagundes De Fagundes | Dreamstime.com

ENERGY IN BRAZIL Brazil's energy planners use IIASA's MESSAGE model to produce long-term energy scenarios for the country. Part of Brazil's energy system is the Itaipu hydroelectric power plant (*above*), which generates enormous amounts of electricity for both Brazil and Paraguay.

Helping countries through the complexities of energy planning is the International Atomic Energy Agency (IAEA)—the only UN agency tasked with building capacity in overall energy planning. Among the tools the IAEA has chosen to assist countries in identifying the most cost-effective energy system is an IIASA- developed systems analysis tool, known as MESSAGE (Model for Energy Supply System Alternatives and their General Environmental impacts). MESSAGE has helped energy planning bodies in more than 80 countries to formulate and evaluate alternative energy supply options for a nation or region, taking into account local constraints.

"MESSAGE has had a big impact on the way energy planning is done in Brazil," explains Prof. Roberto Schaeffer of the Federal University of Rio de Janeiro. In 2002 the IAEA had introduced MESSAGE to a team of Brazilian partners, including Schaeffer, to explore paths to sustainable energy development. The resulting assessment was so successful that the Energy Research Company of Brazil's Ministry of Mines and Energy, the company in charge of producing long-term scenarios for Brazil, has continued to use MESSAGE as one of its official modeling tools ever since.

"Message is a powerful tool for helping countries plan their energy systems because the model aims to find an optimum solution for the energy system as a whole, and not optimum solutions for only specific parts of the system," says Schaeffer. Analysis using MESSAGE begins with an assessment of existing energy infrastructure. Then, based on a range of future expansion scenarios, the tool helps design long-term strategies by analyzing cost-optimal energy mixes, investment needs, and other costs, as well as technical, financial, or policy constraints such as energy supply security or the rate at which new technologies can be introduced.

More recently, the IAEA has been using MESSAGE in a range of ongoing projects in Burkina Faso, Ivory Coast, Mauritania and Niger to determine the levels of power station investment and the kinds of power plant required to meet the growing demand for electricity.

"In Niger," Hans-Holger Rogner, Head of the IAEA's Planning and Economic Studies Section, points out: "The analysis has been hugely informative." Energy planners found large coal reserves in one isolated part of the country where the demand for electricity did not merit the building of a coal power plant. Instead the remote region generated electricity for itself using expensive diesel generators. If electricity demand were to develop, however, then a coal power plant could be sustained.

"MESSAGE showed that interconnecting the remote region to the main grid would give it access to electricity at a lower cost than using its current generators," Rogner explains. The cost of the interconnection could be recouped when demand for electricity (elsewhere in the country and for export) was high enough to merit the coal plant being built. The coal plant could then supply some of the remote region's electricity, with the balance being shipped out of the region, using the transmission system which initially brought electricity in.

"In such ways," Rogner concludes, "the IAEA aims to build the capacities of institutions in developing countries so that they can independently chart their energy demand and supply strategies and test the effectiveness of different energy and environmental policy options. MESSAGE is one of the most commonly used analytical tools for this purpose." ■

Further information IIASA's MESSAGE Model at www.iiasa.ac.at/Research/ENE/model/message.html; IIASA's Energy Program at www.iiasa.ac.at/Research/ENE; IAEA's Planning and Economic Studies Section at www.iaea.org/OurWork/ST/NE/Pess/index.shtml

Dipl.Ing. Manfred Strubegger is a Research Scholar in IIASA's Energy Program and the main developer of the MESSAGE model.

IIASA & IPCC

Assessing climate change

Nine IIASA scientists work on IPCC Fifth Assessment

As the 831 experts selected earlier this year by the Intergovernmental Panel on Climate Change begin work on the IPCC Fifth Assessment Report (AR5), 9 IIASA scientists are heavily involved in the work as review editors and lead authors. This continues the tradition of IIASA scientists playing an important role in doing the science, particularly the data modeling, that dates back to the IPCC's founding in 1988. Their work underlies many of the IPCC climate change reports and assessments. Indeed, 10 IIASA scientists who co-authored the Fourth Assessment Report were among the recipients of the 2007 Nobel Peace Prize, which was given jointly to the IPCC and former U.S. Vice President Al Gore for their work on climate change.

IIASA's approach of merging interdisciplinary and international research ensures a deep scientific understanding of the complexities of climate change, which is reflected in the work IIASA researchers are doing for AR5. Six of the IIASA scientists participating in AR5 are focusing on different aspects of mitigation of climate change. The mitigation section of the report will cover everything from studying finance issues and assessing the risk and uncertainty of climate change policies to looking at the drivers of climate change (such as population and economic growth) and the role these play in mitigation. Energy systems, sustainable development, and assessing transformation pathways are also part of IIASA's mitigation work.

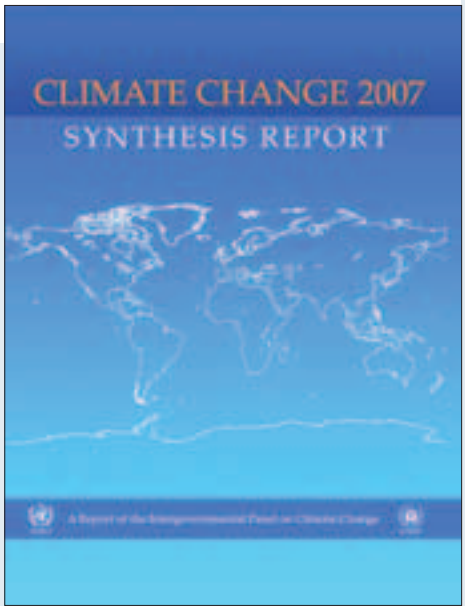
The lead author on the economics of adaptation chapter is also an IIASA scientist, as are two of the review editors. Two other review editors are members of the IIASA Council. Four of the IIASA's AR5 authors are bringing to the IPCC the models and methods they used for the institute's Global Energy Assessment (GEA), which will be published in several months. Indeed the GEA will make a major contribution to the AR5 with 42 GEA authors selected as authors for the AR5.

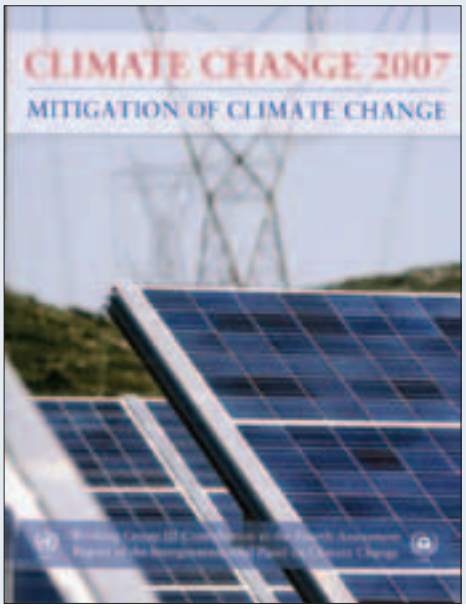
One of the new tools being used for the AR5 climate projections is the "Representative Concentration Pathways" database, which is hosted at IIASA (www.iiasa.ac.at/web-apps/tnt/RcpDb). The database, the result of several years of collaboration among scientific teams, aims at documenting the emissions, concentrations, and land-cover change projections for the four pathways currently in the database. The RPCs, which are projections of the components of radiative forcing, are intended to serve as input for climate modeling, pattern scaling, and atmospheric chemistry modeling.

The RCP developers note that the pathways "jump-start the scenario development across research communities from which uncertainties about socioeconomic, climate, and impact futures can be explored. They thus constitute just the beginning of the parallel process of developing new scenarios for the IPCC's [AR5]."

The Fifth Assessment Report is to be published in either 2013 or 2014, according to IPCC officials. ■

The Intergovernmental Panel on Climate Change
www.ipcc.ch





Clean energy
Multiple benefits

The energy system of the future could develop in a number of different directions, depending on how society and its decision makers prioritize energy objectives, including climate mitigation, energy security, air pollution, and human health. Researchers of the Energy Program at IIASA conducted a study for the Global Energy Assessment, determining that to achieve sustainability, some options are "musts," while others are "choices." The findings are based on a massive modeling exercise that comprehensively evaluates the consequences of different policy choices for the future energy system. The new projections will enable policymakers to make more informed choices about the future energy pathways they need to take, and how integration of different policy objectives can help to minimize the costs of the transformation.

> *Clean energy . . . It's the right thing to do . . . for our environment, it's the right thing to do for our national security, but it's also the right thing to do for our economy . . . .*

So spoke President Barack Obama on a visit to Fremont, California, in May 2010 to highlight renewable alternatives to oil and the burgeoning employment opportunities offered by clean energy. Listening to him were 200 workers at a new Solyndra facility manufacturing solar photovoltaic systems, and an international audience concerned about oil from the Deepwater Horizon blowout continuing to gush into the Gulf of Mexico.

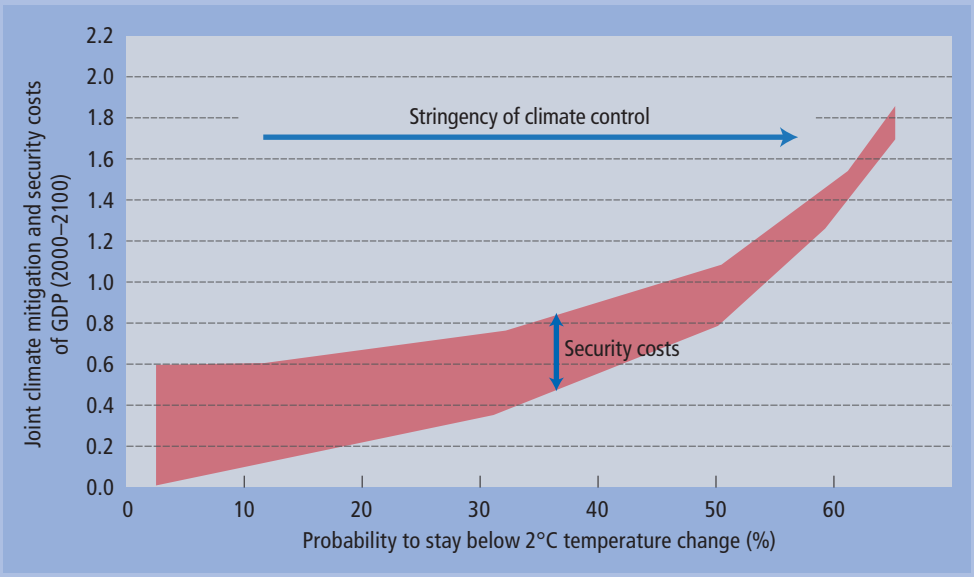
One of today's most pressing concerns are the adverse effects that greenhouse gases (GHGs)—in particular carbon dioxide—emitted in the production and use of fossil-fuel-based energy, are having on the world's ecosystems. With changes occurring more rapidly than previously estimated, world leaders now acknowledge that a transformation of the energy system away from fossil fuels to clean energy is needed urgently to slow and mitigate these impacts.

New work being carried out by IIASA researchers on climate mitigation, energy security, reduced air pollution and health impacts, and affordability of energy within the context of the Global Energy Assessment (GEA) would support Obama's assertions on the benefits of clean energy. In fact, researchers would go further and say that integrating clean energy targets with other energy priorities—such as security—produces enormous synergies between the objectives mentioned by Obama, resulting in significant cost reductions.

The IIASA research is pushing the boundaries of modeling well beyond the objectives used in the GEA to describe sustainability, in one of the few attempts in the scenario literature to explore—holistically—the important relationships between the various different energy objectives. Researchers are using the MESSAGE integrated assessment modeling framework to look at a large ensemble of energy futures.

REDUCING TOTAL POLICY COSTS

Decarbonization to stay below a 2°C maximum temperature requires massive investments. However, the total energy system costs for simultaneously achieving energy security and climate mitigation objectives can be substantially reduced. As regions pursue strategies to mitigate the climate and/or enact policies and procurement strategies that prioritize domestic supplies over imports, the diversity of their energy resource mixes tends to increase. The pursuance of climate mitigation and energy security adds to total energy system costs. The costs of security, however, are significantly reduced at higher levels of decarbonization, highlighting the multiple benefits of the two objectives. ■



SLOW CLIMATE CHANGE, LOWER SECURITY COSTS At lower levels of decarbonization (i.e., correspondingly low 2°C probabilities), security costs can increase total system costs by as much as 0.6 percentage points. In contrast, under stringent climate policies, in which total global policy costs are roughly 1.7% of GDP, the added costs of security become extremely small, approaching zero.

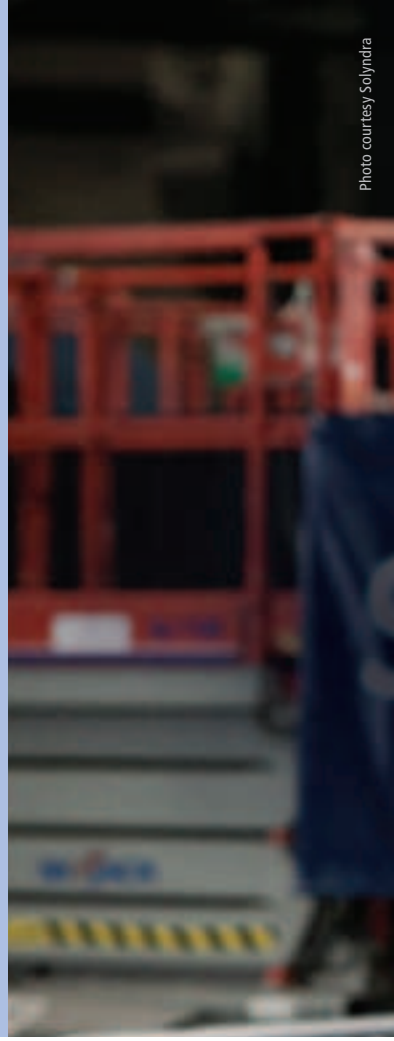


Photo courtesy Solyndra

Integrated assessment of the complex energy sector is vital. Take, for example, the challenge of reaching the commonly discussed long-term goal for climate mitigation, namely, a 2°C maximum temperature rise relative to preindustrial levels to avoid dangerous interference with the climate system. Reaching the 2°C target depends, above all, on making deep reductions in greenhouse gas emissions over the next several decades, a feat that will be principally accomplished by dramatically scaling up the utilization of zero-carbon energy technologies (nuclear and renewables) in the global energy mix so that at least 70 percent of energy sources will be carbon-neutral in the medium term (2050). This will require the upscaling of energy investments to about double the level of today to more than US$1.7 trillion globally—at first glance an expensive transition to make. When analyzed in a holistic and integrated perspective, however, the combined costs of climate mitigation, pollution control, and energy security may come at a significantly reduced total energy bill. In fact, climate mitigation may serve as an entry point both to achieve reductions in pollution control costs of up to 80 percent and to improve energy security, leading to savings of the order of US$800 billion in terms of energy investments.

A related problem from the governance side is that in many countries, separate policy institutions are often responsible for dealing with the different objectives. As a result, the important synergies between these objectives are either overlooked or not understood, and the costs of reaching each objective individually are often overstated. For instance, because zero-carbon energy is pollution-free and can be derived from a variety of sources, it has the potential to significantly decrease air pollution and its corresponding health impacts. Substituting domestically produced renewables (biomass, hydro, wind, solar, and geothermal) for imports of globally traded fossil commodities (coal, oil, and natural gas) reduces pollution, and minimizes impacts not only on the environment (e.g., acid rain) but also on human health (e.g., respiratory tract problems). Diversifying the energy resource mix away from one that relies too heavily on fossil energy can also simultaneously reduce import dependence and enhance energy security. And the more aggressive the levels of decarbonization under scenarios with the most stringent climate policies, the greater the decrease in environmental, health, and security costs. In the most aggressive decarbonization scenarios, the added costs may actually approach zero.

However, while a wholesale reduction in pollution may be the best strategy for minimizing human health and environmental impacts, it may not be the best strategy for the climate. Tradeoffs need to be made. The main pollution–climate tradeoff centers around the small but nontrivial impact that lower levels of air pollutant emissions, namely, climate-cooling aerosols (e.g., SO_2 and OC) and their possible effects on the radiative forcing balance of the Earth—defined by the IPCC Fourth Assessment Report as "a measure of how the energy balance of the Earth–atmosphere system is influenced when factors that affect the climate are altered." Although an "across-the-board" reduction in air pollution tends to increase warming, there are a number of different ways that pollution could be controlled. Specific pollutants are proportionally reduced more than others, for example, warming components, BC, and the ozone precursors—CH_4, NO_x, CO, and VOCs—are reduced more than the cooling components mentioned. Such an effort would tend to preserve the overall cooling effect of aerosols and thus produce a net gain for the climate or at least allow it to remain radiant-energy–neutral. ■

Further information IIASA's Energy Program at www.iiasa.ac.at/Research/ENE and the Global Energy Assessment at www.globalenergyassessment.org

Prof. Keywan Riahi is Acting Leader of IIASA's Energy Program.

CO_2 could sink without trace by 2100

What if the whole CO_2 slate could be wiped clean and substantial amounts of the carbon released into the atmosphere as a result of natural carbon fluxes and the burning of fossil fuels—both historical and current—could be removed from the atmosphere through "negative emissions technology"?

Preliminary data released on 7 October 2010 by the Mauna Loa Observatory in Hawaii shows that the average September 2010 level of atmospheric CO_2 was 386.80 parts per million (ppm). Atmospheric CO_2 has been accelerating upward from decade to decade. In the past 10 years, the average annual rate of increase was 1.91 ppm.

To stave off runaway climate change, several governments have suggested stabilizing global temperature increase at around 2°C above pre-industrial levels, which translates into roughly 400–450 ppm of CO_2-equivalent, or if possible lower. There has always been a bit of a problem with the notion of stabilizing atmospheric greenhouse gases (GHG) at "a safe level." It assumes that a safe level of GHGs actually exists and can be sustained, and also that a safe level can be determined in advance—all in an extremely uncertain environment.

One of the most active debates in the scientific community revolves around the tantalizing possibility that using bioenergy *in combination with* carbon capture and storage (BECCS) could put CO_2 emissions into negative territory.

Biomass is a renewable energy created from living or recently living material. Terrestrial plants such as wood, grasses, and crops, are carbon sinks, absorbing carbon from the atmosphere as they grow through photosynthesis. Most of the so-called first-generation biofuel production in Brazil and the USA is ethanol, produced from sugarcane or corn. In Europe biodiesel is produced principally from rapeseed and soybean oils. The second-generation biofuels, including ethanol and methanol, are produced from ligno-cellulosic biomass—the by-products of forest management and waste from agriculture, such as branches, needles, leaves, and other woody tree parts or straw.

BECCS revolves around using biomass to produce bioenergy, then capturing and diverting the CO_2 produced during combustion/processing into a long-term geological storage facility. Injection of CO_2 in suitable geological reservoirs, which could lead to permanent storage of CO_2, is the most mature of the storage methods, with a number of commercial projects already in operation.

A combination of bioenergy technologies together with CCS could decrease costs and increase attainability of low stabilization levels, producing a "negative emissions" situation and thus dealing a "double whammy" to atmospheric CO_2 emissions: CO_2 fixation by photosynthesis (bioenergy is considered to be carbon-neutral) + capture and storage of CO_2 from biomass combustion (negative emissions). To quote the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), BECCS is "a potential rapid-response prevention strategy for abrupt climate change."

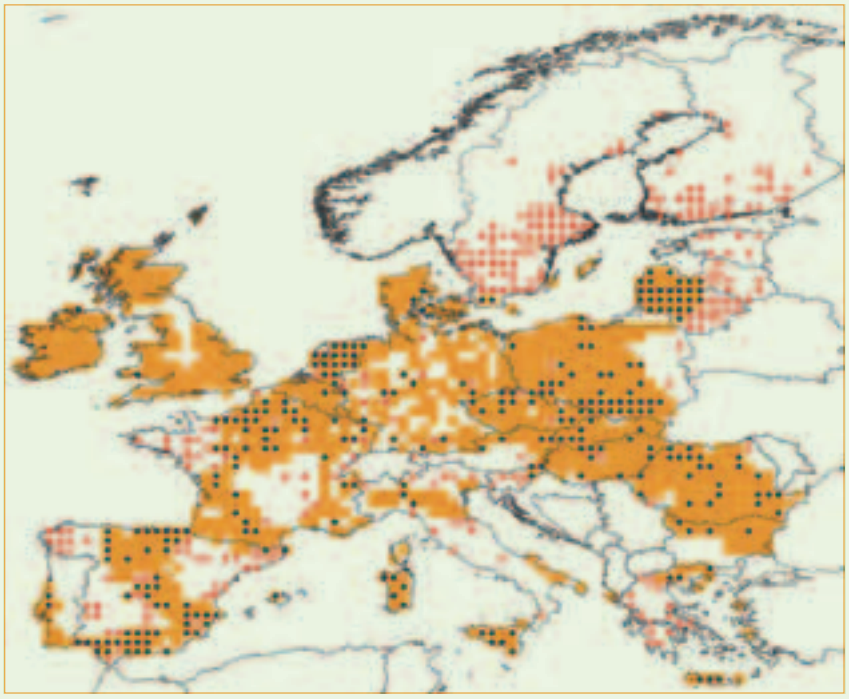
Relatively "simple" technology for bioenergy production, such as biomass CHP (Combined Heat and Power Production), using wood chips, pellets, straw bales, or certain specially grown crops, has been in existence at an industrial scale for a long time. CHP plants capture the heat produced during electricity generation and use it for industry supply and local heating of public and private buildings, right through to district heating—common in Scandinavia as well as in Central and Eastern Europe—for whole communities. In conjunction with this, capturing and storing the CO_2 emissions of

BIOENERGY IN COMBINATION WITH CARBON CAPTURE & STORAGE (BECCS) AND THE 20-20-20 TARGETS

BECCS, using combined heat and power production (CHP) technology, might contribute substantially to reaching the 20-20-20 targets of the European Union (e.g., generating 20 percent of the total energy demand from renewables and reduce total EU emissions by 20 percent until 2020, calculated from a 1990 baseline):

Using the G4M model for forest biomass assessment and the BEWHERE model for optimized scaling and location of bioenergy plants (both models developed by IIASA's Forestry Program), IIASA scientists found that bioenergy production (from green field CHP plants) has the technical potential to contribute more than 60 percent toward achieving the goal of 20 percent renewable energy share in the EU by 2020. When assuming direct injection into suitable geological formations for carbon storage at the location of the bioenergy plants (BECCS), about half of the "carbon-neutral emissions" from these bioenergy plants could be captured, stored, and accounted for as negative emissions (see map).

Concluded IIASA scientists: "much more visibility of the BECCS idea as well as targeted research is needed" and "relevant BECCS policies need to be put in place quickly." ■



BIOENERGY & CCS
The map illustrates the potential bioenergy of CHP (combined heat and power production) plants (100 MW) in EU27 to achieve a 62 percent renewable share of the total energy production in 2020. About half of the plants are placed directly on geological formations suitable for carbon storage. The bioenergy is supplied from European forests under sustainable forest management assumptions and without biomass imports from outside Europe (no competition with any other forest sector industry). *Source*: Kraxner F, Leduc S, Aoki K, Kindermann G, Obersteiner M (2010). *Bioenergy Use for Negative Emissions – Potentials for Carbon Capture and Storage (BECCS) from a Global Forest Model Combined with Optimized Siting and Scaling of Bioenergy Plants in Europe*. Working paper presented at the First International Workshop on Biomass & Carbon Capture and Storage, 14–15 October 2010, University of Orléans, France.

Photo: Vattenfall | Flickr.com

biomass CHP plants has the potential to deliver the highest long-run climate benefits of any energy process: large enough, according to IIASA research, to neutralize even historical fossil fuel emissions, while at the same time satisfying a significant part of global energy and transport fuel demand (i.e., as second-generation biofuel). And the more ambitious the CO_2 reduction is, the more advantageous it becomes from the cost viewpoint to include BECCS in the energy technology portfolio. This implies that BECCS can be considered a pivotal technology for attaining low stabilization targets.

Only very few studies have comprehensively assessed the competitive interactions involved in BECCS and an integrated assessment of the environmental impacts is needed when applied at a very large scale. There are critical issues that need to be taken into account. Large areas of land for biomass production would be required if BECCS is to make a significant contribution to the global carbon budget, and policies will need to be implemented to avoid biomass impinging on food security and/or other environmental goals such as biodiversity. However, it is believed that these limitations may be less constraining later on in the century due to technological improvements and higher efficiencies on both sides—(bio)energy and food production. Another critical issue is the potential to store carbon—this applies to emissions from fossil fuels (CCS) as well as from biomass (BECCS). IIASA scenarios for production on the scale needed to be cost-effective show global carbon storage facilities need to be considerably larger than they are considered at present and hence require further investigation regarding geological suitability.

Technologies that can rapidly remove GHGs from the atmosphere are expected to play an important role in reducing the carbon burden, especially if human welfare comes under threat from climate-change related damage such as catastrophic flooding and sea-level rise. It is suggested that climate policy portfolios emphasize abatement of 50–100 percent by 2050, with complete decarbonization of the energy sector in the following decades. These goals are consistent with the most ambitious goals announced by major emitters. A target of at least 25 percent is necessary in the near term by 2030 as a means of keeping future options open.

The IIASA scientists conclude that increasing deployment of sustainable bioenergy with carbon removal and sequestration, together with a structural shift toward low carbon-intensive fuels, would not only be an important component of a risk-limiting regime, but could also offer a number of ancillary benefits for sustainable development. However, BECCS is presently seen as the only available technology for actively removing CO_2 from the atmosphere at large scale, which could also put energy production from (forest) biomass in a special situation compared with other renewable energy production options such as wind or photovoltaic. ■

Further information Azar C, Lindgren K, Obersteiner M, Riahi K, van Vuuren DP, den Elzen MGJ, Möllersten K, Larson ED (2010). The feasibility of low CO_2 concentration targets and the role of bio-energy carbon-capture and storage. *Climatic Change* 100(1):195–202.

Mr. Florian Kraxner is Deputy Leader and **Dr. Michael Obersteiner** is a Research Scholar in IIASA's Forestry Program.

Tackling short-lived pollutants offers big benefits

While carbon dioxide emissions tend to grab all the global warming headlines, scientists are currently turning their attention to something more down-to-earth: soot

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Image from a NASA computer simulation of the sp

Although carbon dioxide mitigation remains the principal climate target, new understanding is emerging about so-called short-lived climate forcers including black carbon (soot), tropospheric ozone, and methane. Tackling these short-lived climate forcers, scientists now argue, could lead to quickly won benefits ranging from slowing the Arctic ice thaw to improved air quality leading to better health, particularly in developing countries.

The exciting potential of short-lived climate forcers is largely due to their shorter lifespan in the atmosphere compared to long-lived substances such as carbon dioxide (CO_2). As IIASA's Dr. Markus Amann explains: "To solve climate change in the long term we need to reduce the amount of carbon dioxide emitted to the atmosphere. However, CO_2 emissions stay in the atmosphere for over a hundred years. Much of the global warming that will occur in the next few decades is determined from CO_2 *already* in the air. In reality there will be a substantial time lag between measures the world takes today to cut CO_2 and their impact on global warming."

To achieve more rapid results on near-term climate change, particularly at the regional level, IIASA scientists are now eyeing increased control of short-lived warming emissions (see "Non-CO_2 greenhouse gas emissions in the EU," *left*). This, it appears, is one of the few options to prevent irreversible damage to sensitive ecosystems and changes in rainfall patterns in the near term. ▶

NON-CO_2 GREENHOUSE GAS EMISSIONS IN THE EU

Emissions from non-CO_2 greenhouse gases such as methane and nitrous oxide in the EU will decline by 2030, according to a recent IIASA report to the European Commission. Based on the most recent projections of population and economic development, it is estimated that baseline emissions of non-CO_2 GHGs will decline by 14 percent between 2005 and 2030. The primary reasons for this decline include the full implementation of the EU Landfill Directive, the declining number of dairy cows and non-dairy cattle following productivity increases in agriculture, and a decline in coal mining. Analysis further suggests that non-CO_2 GHG emissions from non-ETS (European Emission Trading System) sectors by 2030 can be reduced by up to 41 percent below the 2005 level through full application of currently available technical mitigation measures. ■

Further information Höglund-Isaksson L, Winiwarter W, Wagner F, Klimont Z, Amann M (2010). *Potentials and costs for mitigation of non-CO_2 greenhouse gas emissions in the European Union until 2030.* Report to the European Commission, DG Climate Action. IIASA.

Further

Dr. Markus A
Dr. Lena Höglu
Economic Developm

n (or soot), methane, and tropospheric ozone reside for much less time in the han CO_2 yet exert significant warming effects at the regional scale. For example, on emissions—from diesel engines, cooking stoves, wood burning, and forest re now believed to be responsible for around a quarter of recent warming in rctic (see "Tackling black carbon in the Arctic," *right*).

When suspended in air and deposited on snow, black carbon absorbs sunlight, which warms the air and can accelerate the melting of ice in polar and mountainous regions. Recent research also suggests that black carbon affects the weather through its impact on regional cloud formation and precipitation patterns.

Although black carbon lasts only up to a few weeks in the atmosphere, its warming potential is about 700 times greater than CO_2 during the 100 years following emission. Methane, with its warming effects around 25 times greater than CO_2, has an atmospheric lifetime of only 10–12 years. Such substances also lead to considerable damage to human health, agricultural crops, forests, and natural ecosystems. And, while these pollutants are often the subject of local air pollution control policies, assessing their impact on near-term climate change has to date been largely neglected.

Recently, IIASA scientists have extended IIASA's GAINS (Greenhouse gas—Air pollution interactions and synergies) model to include emissions of short-lived gases and air pollutants. GAINS is an interactive, scenario-generating tool that allows users to identify the best strategies for simultaneously reducing air pollution and greenhouse gas (GHG) emissions. As some short-lived gases cool while others warm the atmosphere, the key to GAINS is its ability to take into account the combined impact of a mitigation measure on a range of gases.

Based on this model scientists identify some 15 practical measures that, together, could reduce the global warming potential from short-lived pollutants by up to 60 percent compared to a baseline projection. All the measures are technically feasible and have been tried and tested.

The 15 measures include 12 technical measures aimed at reducing methane and black carbon emissions, such as the extended recovery of coal mine gas, the wide-scale introduction of pellet stoves and boilers in the residential sector, replacing traditional coke ovens with modern recovery ovens, and installing particle filters on diesel engines. The three non-technical measures are the elimination of biomass cook stoves in developing countries, the ban of open burning of agricultural waste, and enforcing existing legislation to eliminate high-emitting diesel vehicles.

"If these 15 measures were aggressively implemented by 2030, they could reduce global methane emissions by up to 45 per cent, black carbon emissions by some 70 per cent, and carbon monoxide emissions by 55 per cent below our baseline projections," Dr. Amann explains. "The range of potential benefits includes increased human wellbeing from reduced local air pollution, better local environmental quality, reduced near-term climate change at the local and regional scale, increased security in food and energy supply, and lower water demand. In many cases, these measures would also result n more efficient energy use and thereby also reduce emissions of long-lived enhouse gases," he concludes. ■

information A list of sources can be found online at www.iiasa.ac.at/Options/sources

Amann is Leader and **Mr. Zbigniew Klimont**, **Dr. Kaarle Kupiainen**, and **nd-Isaksson** are Research Scholars in IIASA's Atmospheric Pollution and ent Program.

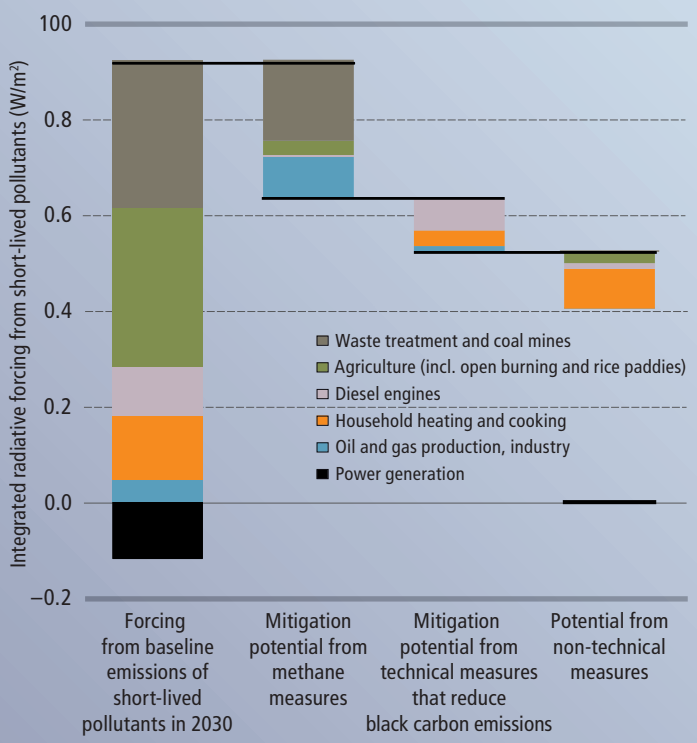
TACKLING BLACK CARBON IN THE ARCTIC

Black carbon from engines and forest fires is collecting in the Arctic where it is creating a haze of pollution that absorbs sunlight and warms the air. It is also being deposited on snow, darkening its surface and reducing the snow's ability to reflect heat back into space. Recent studies suggest that this "soot" has been responsible for around a quarter of the total temperature increases in the Arctic between 1890 and 2007. The Arctic continues to warm more rapidly than almost all other parts of the globe.

Climate processes unique to the Arctic have significant effects that extend globally. The International Panel on Climate Change (IPCC) noted nearly 10 years ago that changes, which include melting of glaciers, sea ice, and permafrost, are already taking place. The consequences include disrupted wildlife migration patterns, altered fish stocks, modified agricultural zones, and increased forest fires. Consequently, as the 2010 Report by the Ad Hoc Expert Group on Black Carbon for the United Nations Economic Commission for Europe suggests, action must be taken in the very near term to reduce the rate of warming in the Arctic in comparison to other areas of the globe.

The 2010 Report argues that while there is no scientific consensus on the overall global climate effect of black carbon, consensus is nevertheless emerging regarding the regional influence of black carbon on areas of snow and ice. For the Arctic, scientists suggest, constraining the length of the ice melt season and, in particular, delaying the onset of spring melt, may best be achieved by targeting shorter-lived climate forcing agents such as black carbon. The benefit of these emission reductions will be felt much more quickly than reductions of long-lived greenhouse gases. ■

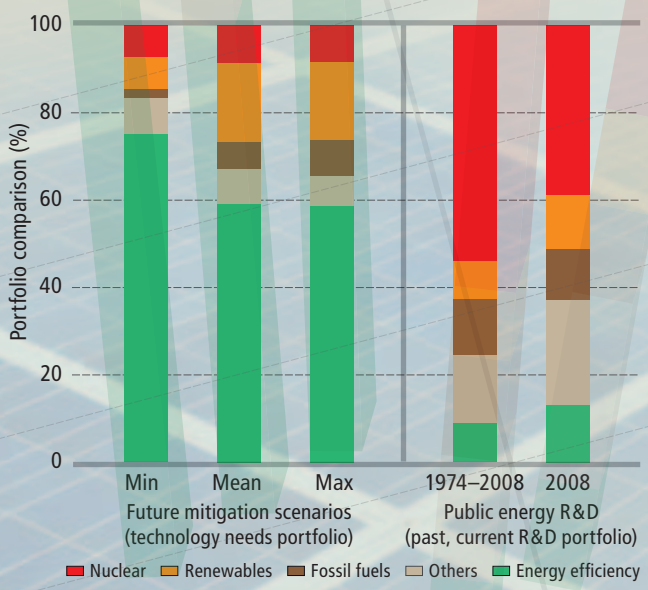
Further information Ad Hoc Expert Group on Black Carbon (including IIASA's Dr. Markus Amman, Dr. Kaarle Kupiainen, & Mr. Zbigniew Klimont) (2010). *Black Carbon*. Report to the Executive Body for the United Nations Economic Commission for Europe's Convention on Long-range Transboundary Air Pollution.



REDUCING THE IMPACT OF SHORT-LIVED POLLUTANTS The left column illustrates the long term impact from the 2030 emissions of short-lived pollutants on radiative forcing, a key driver of temperature increases. The other columns demonstrate the potential to minimize the impact by applying a range of measures.

Getting the right balance in energy R&D portfolios

R&D in energy efficiency has attracted relatively little funding from governments despite energy efficiency having far greater potential to reduce greenhouse gas emissions than other energy technologies



RESEARCH & DEVELOPMENT IMBALANCES Past and current investments into developing climate-friendly technologies (R&D, *right*) versus future technology needs (min/mean/max across scenarios, *left*) by technology category.

An assessment of future scenarios that limit the extent of global warming indicates that unless R&D investment in new, efficient, and clean energy technologies is increased, and supporting policies and market incentives are implemented, greenhouse gas (GHG) emission reduction targets are unlikely to be met, or met only at considerable cost.

The study by IIASA energy technology experts identifies energy efficiency as the single most important option for achieving significant and long-term reductions in GHG emissions, accounting for up to 50 percent of the reduction potential across the wide range of scenarios analyzed. However, investment in energy efficiency R&D has typically been less than 10 percent of the overall public sector R&D budget in the countries of the International Energy Agency (IEA). Conversely, although nuclear energy accounts for less than 10 percent of the GHG emission reduction potentials across all scenarios, it has received some 50 percent of the total public investment in energy technology R&D.

The analysis, published in the inaugural issue of the journal *Carbon Management* in October 2010, compared historical and current government spending on R&D by the 28 member countries of the International Energy Agency, through a "needs"-based analysis of the technologies required to achieve long-term climate stabilization. The assessment is based on the analysis of a wide range of scenarios of future technology deployment rates under a range of future uncertainties and climate constraints.

Current investments in energy technology R&D by the public sector, in all industrialized countries, show a heavy bias in favor of nuclear energy, to the detriment of energy efficiency research. Given their respective importance for future climate mitigation, this is a significant imbalance. Based on current investments, the authors estimate that a fivefold increase in investment in energy efficiency is needed to redress the balance.

According to the study the drastic emission cuts required to limit climate change will only be possible if we can achieve a major a transformation of the energy system. This will require the adoption of a range of policies and measures beyond an expanded and restructured energy technology R&D portfolio to include incentives for niche market applications and the large-scale deployment of climate-friendly technologies.

As the future is inherently uncertain, the study uses a range of scenarios—22 in total—to examine what successful or unsuccessful adoption of different technologies (such as nuclear or carbon capture and sequestration) might achieve for reducing GHG emissions. The scenarios include a "do-nothing" or "business-as-usual" scenario where, for example, R&D policies remain uncoordinated and market incentives for new technologies to minimize emissions remain unchanged. The study concludes that a business-as-usual approach to energy technology R&D will make combating climate change very difficult and more costly, reducing both the likelihood of success and the political and social acceptability of a transition to climate-friendly, energy-efficient technologies.

Based on the scenarios the authors outline a forward-looking energy R&D "portfolio" that they propose would provide the best hedging strategy to ensure that future GHG emissions can be reduced and at reasonable costs. To achieve this goal, currently unbalanced energy technology R&D portfolios need to change to reflect the respective economic values of future GHG mitigation options, which are particularly large for energy efficiency (see chart, *left*).

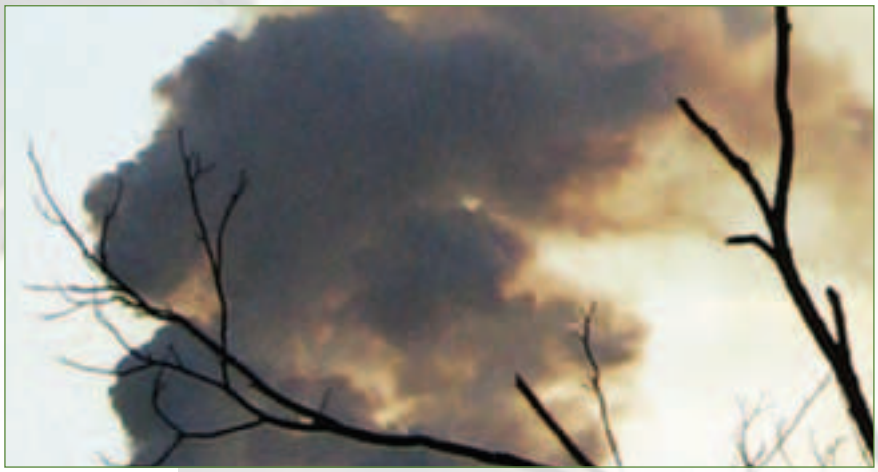
The study, while focused on public or government-funded R&D, identifies a similar pattern of investment in the private sector, where there is a similar preference for large-scale supply-side energy technology investments to the detriment of energy efficiency. ■

Further information Grubler A, Riahi K (2010). Do governments have the right mix in their energy R&D portfolios? *Carbon Management* 1(1):79–87.

Prof. Arnulf Grubler is Acting Leader of IIASA's Transitions to New Technologies Program and **Prof. Keywan Riahi** is Acting Leader of IIASA's Energy Program.

Dealing with uncertainty in greenhouse gas inventories

New research suggests ways to improve the guidance given by the Intergovernmental Panel on Climate Change to countries to determine national greenhouse gas inventories



Since the mid-1990s developed-country parties to the United Nations Framework Convention on Climate Change (UNFCCC) have been publishing annual or periodic inventories of greenhouse gas (GHG) sources and sinks to keep track of changes and estimate their uncertainty. Seventeen papers from the second Uncertainty Workshop held at IIASA on the uncertainty in greenhouse gas inventories have just been published in a Special Issue of the Springer journal *Climatic Change*. While the Intergovernmental Panel on Climate Change (IPCC) stresses the value of conducting uncertainty analyses for inventories and offers guidance on executing them, the recommendations from the new research go well beyond any suggestions it has made to date.

A major finding in the new research was the lack of transparency regarding the methodologies used in national inventories. Researchers found that comparability of national inventories and their uncertainties can be achieved only if details of the methodologies used in analyses are clearly laid out and the results understood in a methodology-dependent context. Researchers found that as uncertainty analyses are still too inconsistent from country to country, inter-country emission-uncertainty analyses/comparisons should not be carried out under the Kyoto Protocol in its current form, which looks at the technosphere and part of the terrestrial biosphere. Thus, as an alternative for the time being, for ideally, global compliance purposes, only the best-known GHGs and subsystems (basically carbon dioxide (CO_2) from fossil fuel burning) could be covered in country reporting. The non-CO_2 GHGs and the entire biosphere, could fall under global reporting. Moreover, the methodology recommended by IPCC GHG inventory guidelines, which recommends splitting emission sources into direct and indirect emissions for analysis using error propagation methodology, was found to be too simplistic. Covering these sources as statistically interdependent with a more elaborate Monte Carlo algorithm, showed greater uncertainty in overall national GHG inventory uncertainty than was obtained using the IPCC method.

The current partial accounting approach to national inventories under the UNFCCC and the Kyoto Protocol was also critiqued. Researchers strongly recommended verified full greenhouse gas accounting, including all sources and sinks of both the technosphere and the biosphere, considered continuously over time, as a prerequisite for reducing uncertainties. The entire system should be looked at bottom-up and top-down so that the system's subsystems can be understood and the uncertainties reduced from both sides (top-down and bottom-up). However, such a bottom-up/top-down monitoring system is not yet in place and it will still take some time until such a system can be implemented.

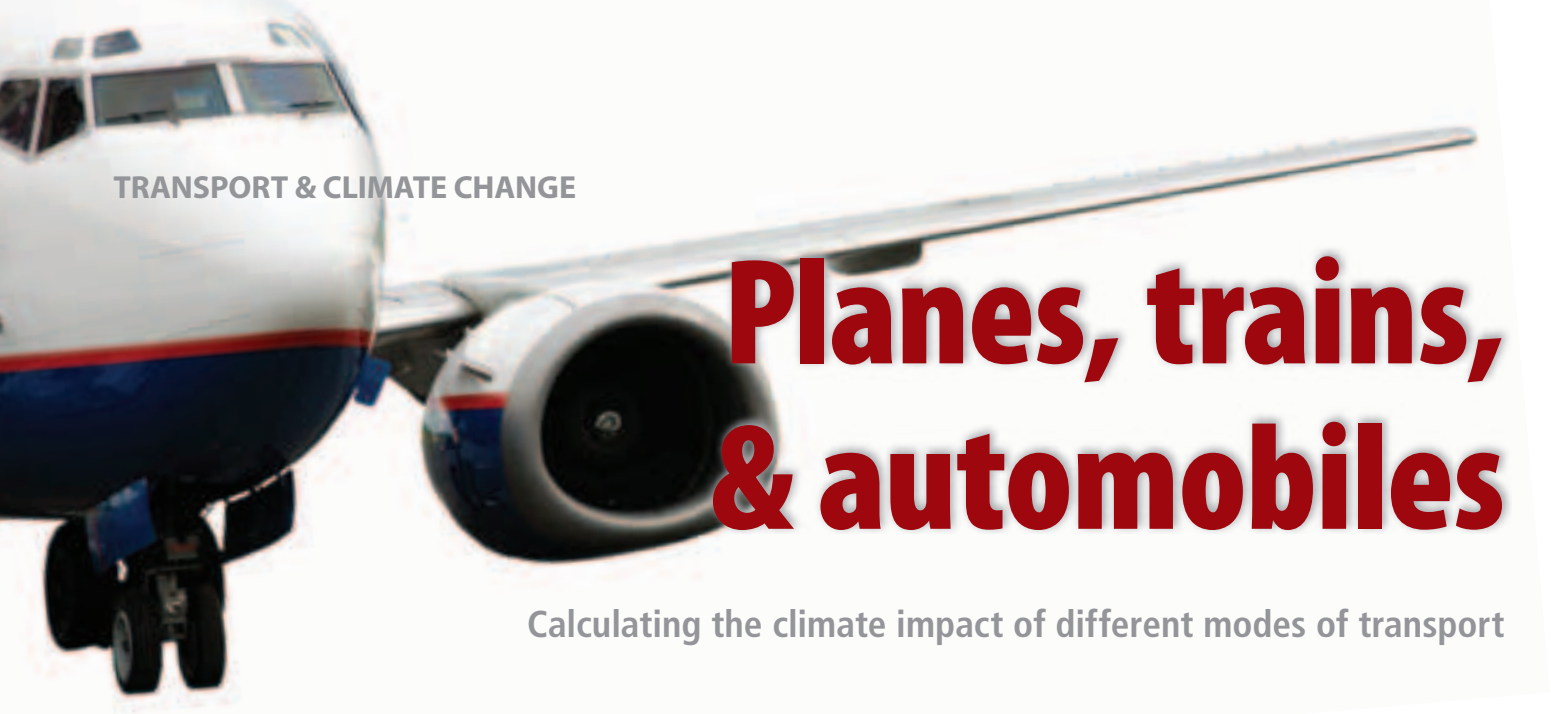
The current policy approach of ignoring inventory uncertainty altogether at the country, sectoral, corporate, or other level, was also deemed problematical, as uncertainty is inherently higher for some GHGs and sectors of an inventory than others. For instance, nitrous oxide emission estimates tend to be more uncertain than those of methane. In the design of future policy agreements, researchers argued, some GHG inventory components would benefit from differentiated treatment. Researchers called on policymakers to decide whether a post-Kyoto agreement will have clear rules for incorporating uncertainty and which parts of an emissions inventory will undergo stringent compliance; and which will be consistently monitored and will undergo stringent reporting (see paragraph 2).

Researchers also considered the fact that inventory uncertainty is not considered to have a bearing on trading of emissions "permits." They advised incorporating reliably and quantitatively assessed uncertainty into emissions trading to allow the required level of emission reductions to be more precisely determined.

The researchers have recently met for a third Uncertainty Workshop held in September 2010 at the Lviv Polytechnic National University and co-sponsored by IIASA. It discussed a number of approaches to addressing uncertainty to improve national inventories and thereby strengthen their usefulness under a compliance and/or global monitoring and reporting framework. ■

Further information Jonas M, Marland G, Winiwarter W, White T, Nahorski Z, Bun R, Nilsson S (2010). Benefits of dealing with uncertainty in greenhouse gas inventories. *Climatic Change* 103(1–2).

Dr. Matthias Jonas is a Research Scholar in IIASA's Forestry Program.



Planes, trains, & automobiles

Calculating the climate impact of different modes of transport

Traveling by plane, train, automobile, bus, or motorbike: Which is the least climate-friendly? According to recent research, it is either the car or the plane, but it depends on what air pollutants are considered and the length of time since the journey.

Carbon dioxide emissions, which remain in the atmosphere for over 100 years, are responsible for warming much of the atmosphere. Yet different modes of transport emit a range of other air pollutants that can dramatically enhance or diminish the overall climate impact from a journey's CO_2 emissions. The lifetime of many of these substances ranges from hours to decades, which means that the magnitude of the climate impact also varies substantially over time.

In comparisons of air and car travel for the same distance and average occupancy level, both modes of transport have an equally adverse climate impact when only CO_2 is considered. However, include the other emissions, and air travel increases global temperatures four times more than car travel in the first years after the journey. Flights at high altitudes have a disproportionately high impact on ozone and clouds which, in turn, has a significant effect on global warming. Yet the larger impact is short-lived. Twenty years after the journey by air is made, the climate impact of flying has fallen to almost half that of driving a car (see chart).

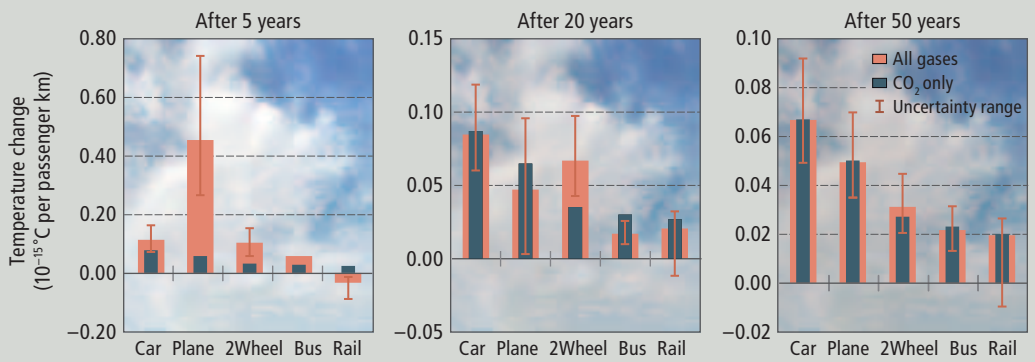
The research was conducted as part of an EU-funded project known as called QUANTIFY (www.ip-quantify.eu) and brought together leading scientists from more than 20 countries, including the USA, India, and China. IIASA researchers developed a new, differentiated emission inventory for the global transport sector for QUANTIFY, and have recently published results with Norwegian research partners in the journal *Environmental Science and Technology*.

Traveling by bus or train are the most climate-friendly modes of transport taking into account the multiple effects of all air pollutants and greenhouse gases. The researchers calculate that passenger trains and buses cause four to five times less impact than automobile travel for every kilometer a passenger travels.

According to Dr. Jens Borken-Kleefeld, lead author of the study: "When it comes to freight transport, moving goods by planes will increase global temperatures between 7 and 35 times more than moving the same goods the same distance in an average truck. On the other hand, shipping exerts 25 times less warming in the long run, and even cools on shorter time scales."

Ships contribute to global warming by emitting carbon dioxide, ozone, and soot. Currently they also emit relatively large amounts of sulfur dioxide which form sulfate particles in the atmosphere that reflect solar radiation back into space and so help cool the planet. This effect is so great that global shipping actually counteracts some of the temperature increases caused by global passenger travel. However, while the effects from the air pollutants will decline over time, the warming from the long-lived CO_2 will accumulate and prevail sooner or later.

The study concluded that as climate change acts at various time scales, it is important to have policies to reduce both air pollutants that have strong, short-term impacts and the other gases that lead to long-term warming. In addition, Dr. Borken-Kleefeld argues: "One comprehensive strategy for tackling climate change caused by the transport sector is actually to minimize the demand for transport." ■



WHICH JOURNEY WARMS THE MOST A comparison of how passenger travel by different modes affects mean global temperatures 5, 20, and 50 years after the journey. The bars also compare the warming effect from only carbon dioxide and the combined effect of all air pollutants and greenhouse gas emissions. Negative values mean cooling, positive values warming.

Further information Borken-Kleefeld J, Berntsen T, Fuglestvedt J (2010). Specific Climate Impact of Passenger and Freight Transport. *Environmental Science & Technology* 44(15):5700–5706.

Dr. Jens Borken-Kleefeld is a Research Scholar in IIASA's Atmospheric Pollution and Economic Development Program.

DEMOGRAPHY & GHG EMISSIONS

Population & climate

How, where, and how long we live can affect climate

Changes in population, including aging and urbanization, could significantly affect global emissions of carbon dioxide over the next 40 years, according to new research

Scientists have long known that changes in population will have some effect on greenhouse gas emissions, but there has been debate as to how large that effect might be.

By mid-century global population could rise by more than three billion people, with most of that increase occurring in urban areas. According to a study published in the *Proceedings of the National Academy of Sciences*, a slowing of that population growth could contribute to significantly reducing greenhouse gas emissions. The researchers found that if by 2050 population followed one of the slower growth paths foreseen as plausible by demographers at the United Nations, this could provide 16 to 29 percent of the emission reductions thought necessary to keep global temperatures from causing serious impacts. The effect of slower population growth on greenhouse gas emissions would be even larger by the end of the century.

Significantly, the slower population growth will have different effects, depending on where it occurs. For example, a slowing of population growth in developing countries today will have a large impact on future global population size. However, slower population growth in developed countries will be very significant for emission levels because of higher per capita energy use—and thus emissions—in these countries.

The researchers sought to quantify how demographic changes influence emissions over time, and in which regions of the world. They also went beyond changes in population size to examine the links between aging, urbanization, and emissions.

The team found that growth in urban populations could lead to as much as a 25 percent rise in projected carbon dioxide emissions in some developing countries. The increased economic growth associated with city dwellers was directly correlated with increased emissions, largely because of the higher productivity and consumption preferences of an urban labor force.

Urbanization was identified as particularly important in many developing countries, especially China and India, while aging was considered a significant factor in industrialized countries, where emissions may be reduced by up to 20 percent in certain countries. This is because older populations are associated with lower labor force participation, and the resulting lower productivity leads to lower economic growth.

The researchers worked with projections showing that population aging will occur in all regions of the world, as a result of people living longer and declines in fertility.

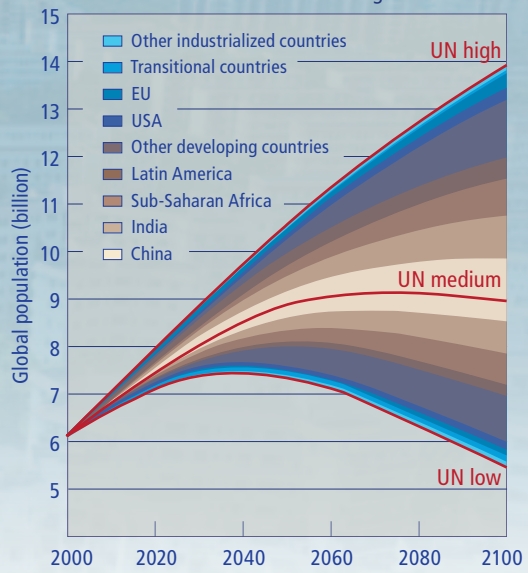
Future scenarios of human behavior

The authors developed a set of economic growth, energy use, and emissions scenarios, using PET, a new Population–Environment–Technology computer model. To capture the effects of future demographic change they distinguished between household types, looking at age, size, and urban vs. rural location. In addition, they drew on data from national surveys covering 34 countries and representative of 61 percent of the global population to estimate key economic characteristics of household types over time, including labor supply and demand for consumer goods. The authors comment that households can affect emissions either directly, through their consumption patterns, or indirectly, through their effects on economic growth.

The authors also suggest that developers of future emission scenarios give greater consideration to the implications of urbanization and aging, particularly in the USA, European Union, China, and India.

They caution that their findings do not imply that policies affecting aging or urbanization should be implemented as a response to climate change, but rather that a better understanding of these trends would help future changes to be anticipated. ■

GLOBAL POPULATION
Projected global totals (solid lines) and regional differences (colored bands) for population size. Individual colored bands indicate the contribution of each region to the difference between global scenarios.



Further information O'Neill BC, Dalton M, Fuchs R, Jiang L, Pachauri S, Zigova K (2010). Global demographic trends and future carbon emissions. *PNAS* 107(41): 17521–17526.

Dr. Brian O'Neill was Leader of IIASA's Population and Climate Change Program and is now at the National Center for Atmospheric Research in the U.S.

Note *This study was initiated by IIASA and supported primarily by funding from the European Heads of Research Councils and the European Science Foundation's European Young Investigators award (EURYI). The study was conducted by researchers from the National Center for Atmospheric Research (NCAR), the International Institute for Applied Systems Analysis, and the National Oceanographic and Atmospheric Administration. Funding was also received from the Hewlett Foundation and the U.S. National Science Foundation.*

RENEWABLE ENERGY

Capturing the sun in North Africa

Will a lack of water stop the development of solar power farms in North Africa?

The Concentrated Solar Power plants dotting the arid countryside around Seville, Spain, typically generate 50 MW of power, which is small compared to traditional coal-fired plants. But Spain's CSP generators—nearly a dozen now in operation and more than 50 on the drawing board—are more than solar power plants. They represent a path to a clean, carbonless energy future.

However, while Spain is aggressive in its effort to expand CSP plants, the countries of North Africa that have the planet's greatest source of solar power in the Sahara Desert, are only reluctantly embracing the emerging technology. There are CSP projects in Algeria, Morocco, and Tunisia, but as the industry publication *CSP Today* noted, the "high costs of this technology and low levels of government support slow the progress of CSP in the region."

The high cost of CSP in the Sahara region is attributed in part to the lack of water, which is needed for cooling the plants. The prevailing wisdom is that without abundant cooling water, CSP power generation won't be efficient or economical.

IIASA energy policy analysts Kerstin Damerau, Keith Williges, and Tony Patt addressed the argument directly in a study entitled "Will Water Availability Defeat the Development of Concentrated Solar Power in North Africa?" There is a great deal at stake in the question, for widespread development of CSP generators in North Africa could bring thousands of jobs to a region that needs them and spur more widespread economic development in manufacturing and support industries.

Beyond the beneficial impact on North Africa, the authors note that Europe is "relatively lacking in undeveloped arid land" and significant development of CSP in North Africa could not only provide power there, but could "fuel electricity export to Europe via high voltage direct current cables." Plans have moved forward with a French-backed regional initiative called the Mediterranean Solar Plan, which has a target of 20 GW of new solar and wind generation, and the Desertec Industrial Initiative, a consortium of energy, technology, and financial firms that want to raise €440 billion in CSP investment in the Sahara Desert.

But the significant technological question regarding cooling water remains a hurdle for CSP development in North Africa. For the IIASA researchers, it's a matter of trade-offs—power generation efficiency versus cooling water; the more the cooling, the more efficient the CSP plant.

The researchers studied the alternatives to water-intensive wet cooling and found that dry cooling, dry cooling with spraying, and a hybrid system that involves both wet and dry cooling do add initial cost and reduce operating efficiency, but not nearly to the extent that is commonly assumed in the industry.

"There is a trade-off," Patt said, "but the big message is that it isn't that bad. People have said it's a really big problem, and it isn't."

The researchers looked at the numbers for CSP plants in southern Spain and the Mojave Desert in the USA and determined that "the difference from wet to dry cooling amounts to 3 percent annual output loss (for the Spanish plant) and 5 percent in the Mojave Desert." With the extremely hot temperatures in the Sahara, they put the operating loss number at between 5 and 10 percent. As for the initial investment, installing dry instead of wet cooling systems for large CSP plans increases the costs by about 2 to 3 percent, depending on the type of system used.

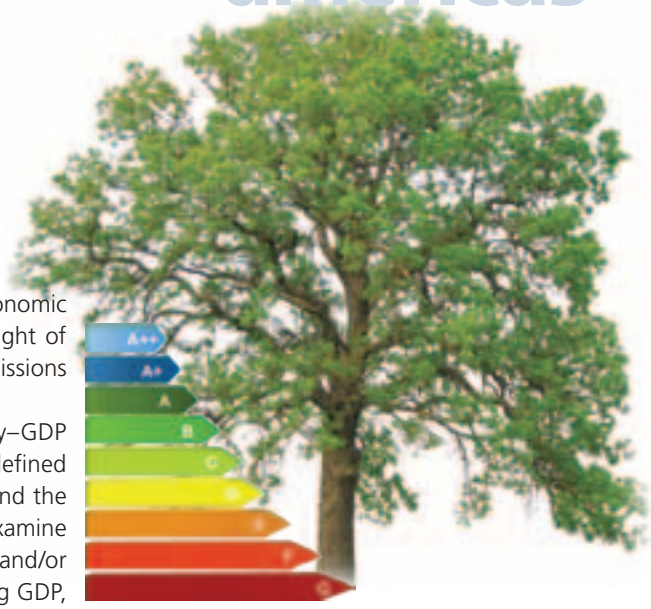
Photo: © Dana Smillie / World Bank

SOLAR POWER IN MOROCCO The Ain Beni Mathar solar thermal power plant enjoys abundant sunshine and has enough water to cool the power station and clean the solar mirrors. It also can diversify its energy sources between solar and thermal power.

CSP in the Sahara region, with its potential for bringing power to Europe and jobs to North Africa, could be an important source of future clean energy generation, Patt said. While the "energy–water nexus" is a key issue in creating sustainable electricity generation, he said, "there are already technical solutions for reducing a high water demand and supplying plants with sustainable water sources." The future of CSP in North Africa, he concluded, "does not depend on technical limitations or major economic penalties, but it does depend on political regulation and governance to ensure an ecologically sound development." ■

Further information IIASA's Risk and Vulnerability Program at www.iiasa.ac.at/Research/RAV

Ms. Kerstin Damerau and **Mr. Keith Williges** are Research Assistants, and **Dr. Tony Patt** is a Senior Research Scholar all in IIASA's Risk and Vulnerability Program.



ENERGY

Energy efficiency key to growth

What is the long-term relationship between energy consumption and economic growth? Interest in this question is gaining new momentum in the light of growing concerns about climatic change and proposals to limit CO_2 emissions by restricting fossil fuel consumption.

Research from IIASA recently tackled this issue by examining the energy–GDP relationship for the USA in the 1946–2000 period. In the study, researchers redefined energy in terms of exergy (the amount of energy available for useful work) and the amount of useful work provided from energy inputs. This enabled them to examine whether output growth depends on either the quantity of energy supplied and/or the efficiency of energy use. Two multivariate models were estimated involving GDP, capital, labor, and these two measures of energy.

Key findings indicate that output growth is "driven" by increased availability of energy and the increased delivery of useful work to the economy. Researchers conclude that to sustain long-term growth it is necessary to increase the efficiency of energy usage. Alternatively, energy supplies could also be increased but limited energy resources make this less likely.

"In a world of ever-increasing energy prices, concerns over energy security, and the harmful effects of fossil fuel consumption, recourse to increased energy efficiency as a driver of growth provides hope for sustained future wealth creation," points out IIASA's Robert Ayres. "This indicates that government efforts should concentrate on identifying and supporting the most economically feasible and technologically desirable means to maintain year-on-year energy efficiency improvements in order to sustain output growth." ■

Further information Warr B, Ayres R (2010). Evidence of causality between the quantity and quality of energy consumption and economic growth. *Energy* 35:1688–1693.

Prof. Robert Ayres is an IIASA Institute Scholar and Professor Emeritus, INSEAD.

POPULATION CHANGE Comparing fertility among religions in the USA (2003).

Religious groups	Total fertility rate
Muslims	2.84
Hispanic Catholics	2.75
Black Protestants	2.35
Fundamentalist Protestants, excluding Blacks	2.13
Non-Hispanic Catholics	2.11
Moderate Protestants, excluding Blacks	2.01
Liberal Protestants, excluding Blacks	1.84
Hindus/Buddhists	1.73
No religion	1.66
Others	1.64
Jews	1.43
U.S. population average	2.08

WORLD POPULATION

U.S. population trends a matter of faith

New IIASA research into the religious composition of the United States suggests that between 2003 and 2043 there will be a rapid growth in the population of Hispanic Catholics from currently 10 to 18 percent of the American population.

In the first study of its kind, researchers projected the size of 11 American religious groups to 2043, taking into account the impact of religion on fertility (see table, *bottom left*) and how immigration affects the religious composition of the population. Explains IIASA's Vegard Skirbekk: "We find considerable stability of religious groups over time, but there are some important shifts."

The Hispanic Catholic population, he adds, will experience the strongest growth rates because of immigration, high fertility, and a young age structure. Protestants are projected to decrease from 47 to 39 percent of the total population over the same period. Catholicism will emerge as the largest religion among the nation's youngest age groups by mid-century. "This represents a historic moment for a country that has had a Protestant majority since Independence," Skirbekk points out.

Findings further indicate that immigration will drive growth among the Hindu and Muslim populations, while there will be a decline in the Jewish population due to low childbearing levels and a mature age structure.

"Both fertility and immigration will play a significant role in the recasting of America's religious composition in the 21st century," Skirbekk concludes. "As religion has such an influence on fertility through, for example, the contraceptive ban and the promotion of early marriage, projections on future religious composition can enable us to make more realistic projections about population growth as a whole." ■

Further information Skirbekk V, Goujon A, Kaufman E (2010). Secularism, Fundamentalism, or Catholicism? The Religious Composition of the United States to 2043. *Journal for the Scientific Study of Religion* 49(2):293–310.

Dr. Vegard Skirbekk is Leader of the Age and Cohort Change Project,
Dr. Anne Goujon is a Research Scholar in IIASA's World Population Program.

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ENERGY

Accounting for a city's carbon footprint

Greenhouse gas (GHG) accounting that measures only direct emissions provides just a partial picture of the carbon footprint of a city, according to new IIASA research based on a case study example of the city-state of Singapore.

Cities typically import most of their energy requirements as secondary energy products based on conversion processes which cause emissions elsewhere. Emission estimates therefore require attention beyond direct onsite activities within the city. Hence, a comprehensive approach to greenhouse gas accounting for cities should include upstream and downstream processes of connected socioeconomic systems and the indirect life-cycle related emissions of imported and exported goods, suggests IIASA's Niels Schulz.

In a longitudinal study of Singapore, Schulz compared results for GHG emissions under different accounting conventions. First, researchers focused only on direct emissions from activities on the territory. Second, they included indirect emissions from upstream activities. Third, they considered exports of indirect emissions, allowing them to arrive at a trade-corrected net account for indirect emissions.

Findings for Singapore reveal that the volume of indirect emissions was important, with imports of indirect emissions exceeding direct emissions by a factor of 4–5. The study also shows that exports of indirect emissions were generally lower but of a similar order of magnitude, between 3 and 4 times that of direct emissions.

"These findings indicate that existing urban-scale emission accounts might be of limited value," Schulz argues. "Given the increasing trends in world trade and urbanization, indirect pressures of urban systems should be included in future discussions of effective and fair adaptation and mitigation strategies." ■

Further information Schulz NB (2010). Delving into the carbon footprints of Singapore—Comparing direct and indirect greenhouse gas emissions of a small and open economic system. *Energy Policy* 38:4848–4855.

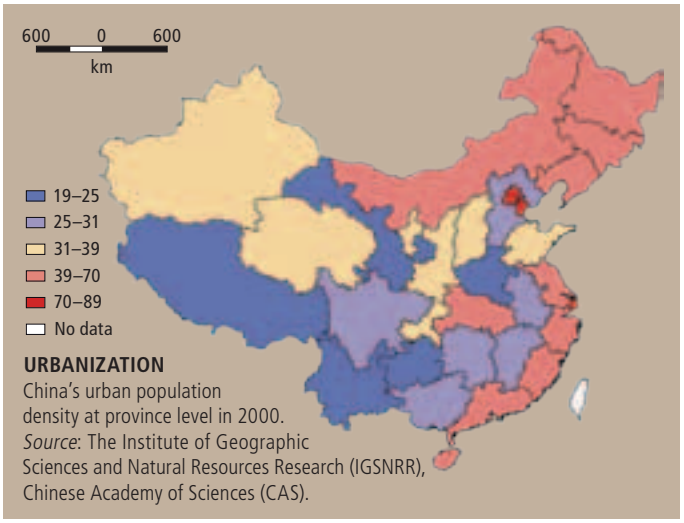
Dr. Niels B. Schulz is a Research Scholar in IIASA's Transition to New Technologies Program.

DEMOGRAPHY

China's urbanization challenge

According to new IIASA research, China's rapid urbanization is set to accelerate yet further. Based on a range of population growth scenarios, researchers suggest an almost doubling of China's urban population by 2030. The migration of younger rural workers to urban areas will result in the labor force taking a larger share of total population in urban than rural areas. Such rapid urbanization, the report points out, presents major economic, demographic, environmental, and energy challenges.

China has experienced unprecedented urbanization over the past half century due to rapid economic growth and increasing globalization of its domestic economy. The rise of China's manufacturing sector has drawn a mass of non-skilled rural workers from the central and western areas to the country's eastern coast towns and cities (see map). Consequently, China's urban population rose from 17 to 43 percent between 1978 and 2008.



URBANIZATION
China's urban population density at province level in 2000.
Source: The Institute of Geographic Sciences and Natural Resources Research (IGSNRR), Chinese Academy of Sciences (CAS).

China's urban land expansion is now considered a threat to agricultural production. Two-thirds of cities currently suffer from some degree of water scarcity, and some cities suffer from air and/or water pollution. In addition, the continued migration of younger workers from rural to urban areas is causing agricultural land to be abandoned in some regions and the rapid aging of China's rural demographic profile.

Lower educational levels in rural areas are considered a further challenge to China's desired transformation from an export-driven to domestic demand-driven economy. According to IIASA's Gui-Ying Cao, "Integrating rural and urban economic-social development and achieving sustainable urban development presents a formidable challenge for the next decades." ■

Further information Cao G-Y, Chen G, Pang L-H, Zheng X-Y, MacKellar L, Nilsson S (2010). Urban growth in China: Past, prospects, and impact. *Population and Environment* (forthcoming).

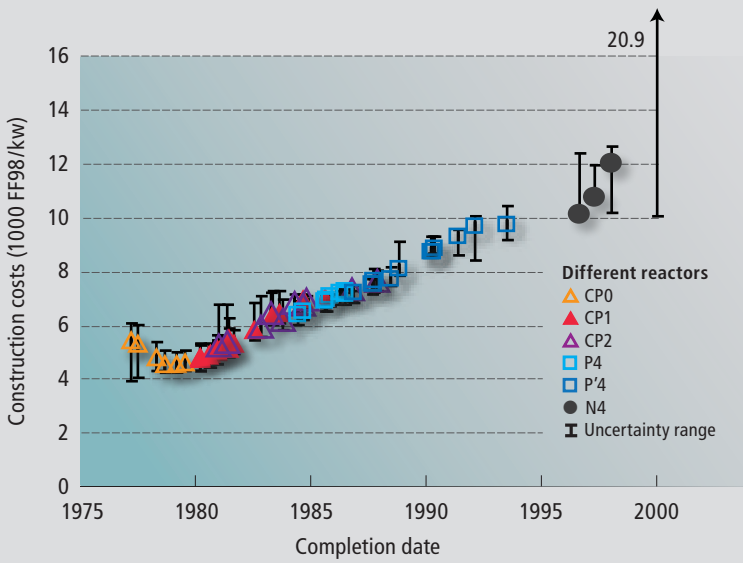
Dr. Gui-Ying Cao is a Research Scholar in IIASA's Forestry Program and **Dr. Landis MacKellar** is Leader of IIASA's Health and Global Change Project.

ENERGY

Costly lessons of nuclear scale-up

Since the early 1970s, the ambitious French nuclear Pressurized Water Reactor (PWR) program has been widely regarded as the most successful scaling-up of a complex and capital-intensive energy technology system in the recent history of industrialized countries.

Yet, according to a new study carried out by IIASA, even this most successful nuclear scale-up was characterized by a substantial escalation of real-term construction costs. This should not be ignored, the research argues, by those considering the potential role of nuclear in a climate mitigation technology portfolio.



GROWING COSTS The construction costs, in 1000 French Francs (5.9FF = 1US$) per kilowatt, for each of the 58 French PWR nuclear reactors increased.

France built 58 PWRs during its PWR construction program which ended in 2000. On completion of the program, the reactors were producing close to 80 percent of France's electricity. Key to the success of this program, IIASA's Arnulf Grubler explains, were a "unique institutional framework that allowed for centralized decision making, a high degree of standardization, and regulatory stability; and a powerful, engineering-savvy, national utility that acted both as principal and agent in reactor construction. Together the framework and the utility enabled comparatively short reactor construction times."

Despite the favorable institutional setting and the fact that operating costs for the new reactors remained low and flat, IIASA research shows that there was a substantial escalation in real (i.e., inflation-adjusted) construction costs for the PWR program (see chart, *top right*). The last and largest series of PWR reactors, the N4—the precursor to the current EPR reactor—turned out to be the most expensive of all French reactors built. This finding, says Grubler, illustrates the perils of assuming that economies of scale and "learning-by-doing" effects will always result in lower costs over time in the scale-up of large, complex, new energy supply technologies. Technology scale-up, he points out, can also lead to cases of "negative learning" in which specific costs increase rather than decrease with accumulated experience.

Grubler suggests that energy technology and climate policy analysts should remember the engineering rule of thumb that large-scale infrastructure construction projects always tend to cost two to three times more than the original estimate. ■

Further information Grubler, A (2010). The costs of French nuclear scale-up: A case of negative learning by doing. *Energy Policy* 38:5174–5188.

Prof. Arnulf Grubler is Acting Leader of IIASA's Transitions to New Technologies Program.

BIOMASS & BIOENERGY

Eastern Europe's biofuel potential

Land availability in Europe is not a limiting factor for reaching ambitious EU renewable energy targets in the transport sector.

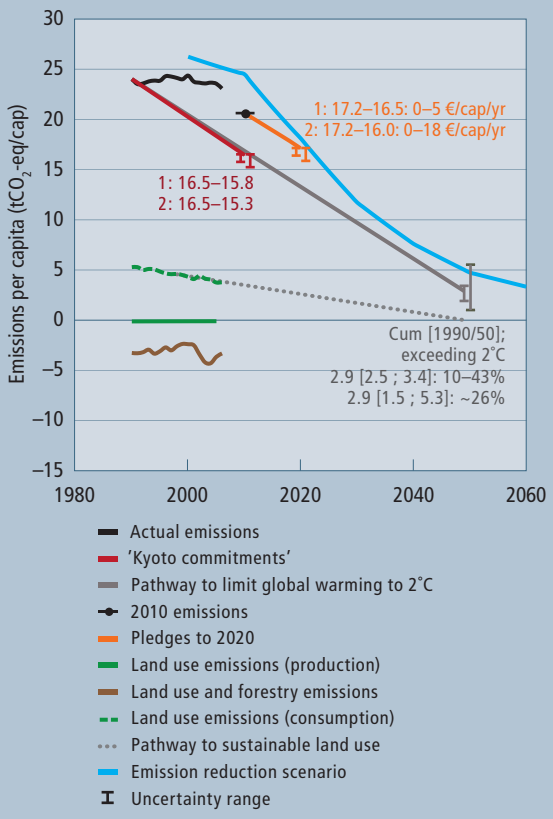
An IIASA study assessed how much agricultural land there was in Europe over and above that required for projected food and animal feed. Findings suggest that some 44–53 million hectares of Europe's cultivated land (including Ukraine) could potentially be available for bioenergy feedstock production by 2030.

At present Europe's agricultural land (including Ukraine) comprises 164 million hectares of cultivated land and 76 million hectares of permanent pastures. Food demand in Europe is likely to remain relatively stable at current levels, while technological progress in agricultural production is expected to continue. Yields today in Central and Eastern Europe (CEEC) are only half those in Western Europe. However, ongoing investments and improvements in the CEEC are expected to bring Western Europe and CEEC yields and feed conversion efficiencies into convergence.

A widespread concern about bioenergy is its potential adverse impact on food security if it takes land away from food production. The analysis of IIASA's Land use Change and Agriculture Program demonstrates that over time significant agricultural land reserves could be freed up for bioenergy without compromising Europe's food and feed sectors. However, this land is unevenly distributed across Europe and by far the largest land potential is located in Eastern Europe. This underlines the importance of development and modernization of the agricultural sector in the CEEC countries. ■

Further information Fischer G, Prieler S, van Velthuizen H, Berndes G, Faaij A, Londo M, de Wit M (2010). Biofuel production potentials in Europe: Sustainable use of cultivated land and pastures, Part II: Land use scenarios. *Biomass and Bioenergy* 34:173–187.

Dipl.Ing. Günther Fischer is Leader, **Dr. Sylvia Prieler** and **Dr. Harrij van Velthuizen** are Research Scholars in IIASA's Land Use Change and Agriculture Program.



PROGRESS TO AVOIDING ADVERSE CLIMATE CHANGE

The figure shows that each individual within the USA must reduce his or her GHG emissions by on average 90 percent between 1990 and 2050. The solid gray line indicates a reference pathway that emissions must follow to achieve the universal per capita target of 2.9 t CO_2-eq. Countries that emit quantities above this line will need to compensate by emitting below the gray line before 2050 to ensure the target is reached.

The solid black curve shows the emissions of the six GHGs (not including emissions from land use) between 1990 and 2006 as reported by the USA to the United Nations Framework Convention on Climate Change (UNFCCC).

Underneath, the red line shows what per capita emission levels the USA would have committed to had it ratified the Kyoto Protocol. The solid black dot represents the U.S. estimated emissions for 2010 followed by an orange line showing expected per capita emissions according to the "2020 pledge" made by the USA (data from IIASA's GAINS model: Greenhouse gas—Air pollution interactions and synergies model). The uncertainty ranges at the end of the red and orange lines take into account: (1) uncertainty in the GHG inventories in both the base year and the target year, and (2) uncertainty in the GHG inventory in only the target year.

The solid blue line represents a typical aggressive emission reduction scenario that aims to lower carbon dioxide in the atmosphere to 360ppm by 2100 (land use is excluded). Even such a scenario fails to meet the condition of equal emission shares above and below the gray reference pathway. The solid green line is an estimate of the emissions from land use within the territory of the USA and the thin brown line shows the land use, land-use change, and forestry (LULUCF) emissions reported by the USA under the UNFCCC. The broken green line is a zero-order estimate of the USA's share of emissions from global land use if a consumption rather than a production approach is followed in accounting for emissions. The dotted gray line represents the path to lower these emissions to zero by 2050 assuming that emissions from land use achieve sustainability. ■

Accounting for uncertainty

A new template evaluates the efforts for an individual country to reduce its greenhouse gas emissions in the short term with the long-term aim of avoiding adverse climate change

Following the 2009 UN climate change conference in Copenhagen, leaders of the world's major industrialized countries agreed that the average global temperature should not increase by more than 2°C from its pre-industrial level. To achieve this target, cumulative greenhouse gas (GHG) emissions must be substantially reduced, but by how much? Taking the USA as an example, new research aims to calculate a realistic figure for GHG emission reduction which takes account of the significant uncertainty surrounding greenhouse gas estimates.

Scientists argue that national emissions estimates must be verified using both "bottom-up" independent oversight of the inventories and better "top-down" monitoring of the emissions in the atmosphere. Nevertheless, both calculations of GHG emissions contain uncertainty for a variety of reasons such as the availability of sufficient and appropriate data and the techniques to process them. Until recently, relatively little attention has been devoted to how uncertainty in emission estimates is dealt with and how it might be reduced. This situation is now changing, with "uncertainty analysis" increasingly recognized as an important tool for improving inventories of GHG emissions and removals.

A collaborative project between researchers from IIASA, the Oak Ridge National Laboratory Carbon Dioxide Information Center (CDIAC), and the Polish Academy of Sciences (SRI), aimed to put emission uncertainties into a wider quantitative context. Their research illustrates emission paths that would comply with the 2°C temperature target while comprehensively accounting for uncertainty.

Findings based on provisional results for a typical data-rich country (i.e., the USA) are shown in the graph. "What this diagram tells us is that each individual within the USA must reduce on average his or her GHG emissions by about 90 percent between 1990 and 2050," IIASA's Matthias Jonas points out. "This task would be equally large for people in Australia and the Russian Federation, and slightly less at 80 percent for those living in the European Union. Achieving such a target would limit the risk of global temperatures rising beyond 2°C to between 10 and 43 percent and so avoids global warming consequences beyond this 'threshold.'"

The research also examined how to narrow down the risk of exceeding 2°C global warming from anywhere between 10 percent and 43 percent to about 26 percent. The result showed that the uncertainty of an individual GHG emission target increases from between 2.5 and 3.4 to between 1.5 and 5.3 t CO_2-eq. Ongoing work ranges from combining uncertainties contained in GHG emission inventories and in the models that estimate emissions, to applying this approach to other countries, and including emission reduction targets based on alternative criteria to carbon dioxide equivalent emissions per capita. ■

Further information Jonas M, Krey V, Wagner F, Marland G, Nahorski Z (2010). Dealing with Uncertainty in Greenhouse Gas Inventories in an Emissions Constrained World. Presented at the third International Workshop on Uncertainty in Greenhouse Gas Inventories, 22–24 September 2010, Lviv, Ukraine.

Dr. Matthias Jonas, **Dr. Volker Krey**, and **Dr. Fabian Wagner** are Research Scholars in IIASA's Forestry Program, Energy Program, and Atmospheric Pollution and Economic Development Program, respectively.

YOUNG SCIENTISTS SUMMER PROGRAM

Scholarships for young scientists from developing countries

IIASA is offering scholarships for up to three exceptional young scientists from developing countries to take part in the Institute's Young Scientists Summer Program (YSSP) in 2011. The scholarships will provide talented PhD students with the opportunity to spend a summer in IIASA's international, interdisciplinary research environment. Since the YSSP was established in 1977, over 1,500 students from 80 countries have benefited from collaborating with IIASA's scholars and enhanced their own perspectives and career opportunities. Following the Program, the participants return to their home countries with new skills and a worldwide network of research contacts.

Participants say the YSSP expands their research perspectives. "The YSSP helped me look at my research from fresh angles," says Sarah Elizabeth Staveteig, who took part in the YSSP in 2004 while studying for her PhD at the University of California, Berkeley. "It offered the springboard I needed to move from coursework to productive independent research. I've returned with a potential dissertation chapter, lots of new ideas on how to proceed, and a new network of colleagues, friends, and potential collaborators from around the world."

The YSSP also enhances careers. "My YSSP experience transformed my career," notes Jesse H. Ausubel about his time at IIASA in 1979. Today, Ausubel is the Director of the Program for the Human Environment at Rockefeller University in New York. "It introduced me to many new areas of science, to many new colleagues with whom I continued to collaborate, and to a global view of problems."

The scholarships, which are funded by private donations, will enable young scientists from developing countries that are not IIASA member countries (see page 2) to join about 50 young scientists like Dr. Staveteig at IIASA in Austria.

▶ Apply online before 17 January 2011 for the YSSP: yssp.iiasa.ac.at/register

▶ Donate today and make an impact on the future of a young researcher in a developing country: www.iiasa.ac.at/donate

"Most participants are from IIASA's member countries," explains IIASA Director Detlof von Winterfeldt. "We hope the scholarships will attract high-quality applicants from other countries and so further the cultural diversity in the program."

Fundraising for the scholarships began at the 2010 YSSP awards ceremony. This year's young scientists donated over €500 toward the first scholarship so that young scientists from developing countries can benefit from attending the YSSP just as they have done. ■

yssp.iiasa.ac.at

POSTDOCTORAL PROGRAM

2010 IIASA postdoctoral fellows announced

IIASA has awarded its 2010 postdoctoral research fellowships to Nuno Bento of Portugal and Xiaojie Chen of China. The fellowships provide opportunities to the two to engage in their own research for between one and two years within one of IIASA's research programs.

Nuno Bento, who completed his PhD in Economics at the University of Grenoble in France this year, will join IIASA's Transitions to New Technologies Program in March 2011. He is investigating growth dynamics in transport, looking not only for stronger patterns of change in the sector, but also new patterns pointing to a more structural change in response to rising urbanization and associated environmental issues.

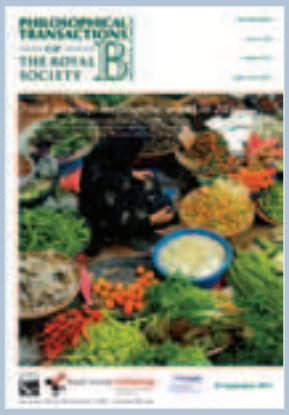
Xiaojie Chen's research focuses on the evolutionary dynamics in biological and social systems, especially the emergence and stability of cooperation in social networks, by using evolutionary game theory and adaptive dynamics. Chen, who will join IIASA's Evolution and Ecology Program in January 2011, is completing a PhD in Dynamics and Control of Complex Systems at Peking University, China.

Bento and Chen join five other postdoctoral fellows currently researching at IIASA in fields ranging from demographic research methods to how urbanization affects the transmission of mosquito-borne disease. Their time at IIASA helps the postdoctoral fellows to develop their knowledge and experience, build a network of contacts, and publish and develop a reputation in research circles. IIASA itself benefits from the influx of these creative and highly trained scientists with their up-to-the-minute knowledge and youthful enthusiasm.

The application period for IIASA postdoctoral scholarships for 2011 started in November 2010 and closes on 28 February 2011. ■

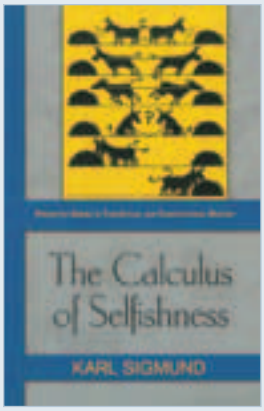
www.iiasa.ac.at/pdocs

publications



Feeding the World in 2050

This special issue of the journal *Philosophical Transactions of the Royal Society B* examines long-term food supply trends given the relentless pressures of population growth, climate change, and increasing demand for water. IIASA demographers and forestry experts contributed to the issue, which looks at the complexities of long-term population growth and uses IIASA's GLOBIOM model to illustrate land use projection uncertainties.
Godfray HCJ, Beddington JR, Crute IR, Haddad L, Lawrence D, Muir JF, Pretty J, Robinson S, Toulmin C (2010). Food security: Feeding the world in 2050. *Philosophical Transactions of the Royal Society B* 365(1554).



The Calculus of Selfishness

How does cooperation emerge among selfish individuals? When do people share resources, punish those they consider unfair, and engage in joint enterprises? These questions fascinate philosophers, biologists, and economists alike, for the "invisible hand" that should turn selfish efforts into public benefit is not always at work. *The Calculus of Selfishness* looks at social dilemmas where cooperative motivations are subverted and self-interest becomes self-defeating. IIASA's Karl Sigmund, a pioneer in evolutionary game theory, uses simple well-known game theory models to examine the foundations of collective action and the effects of reciprocity and reputation.
Sigmund K (2010). *The Calculus of Selfishness.* Princeton University Press, Princeton, USA.

Global Sustainability: A Nobel Cause

If some nine billion people are to live a decent life on our crowded planet we will require, above all else, a steady and affordable supply of freshwater, food, fibers, and fuel—the natural capital that forms the basis for a continuous generation of wealth. This book brings together the advice from some of today's finest minds on how to deliver natural capital in a sustainable manner. IIASA's Nebojsa Nakicenovic is among the contributors which include Nobel laureates and top-level political leaders; he writes on energy research and technology for a transition toward a more sustainable future.
Schellnhuber HJ, Molina M, Stern N, Huber V, Kadner S (eds) (2010). *Global Sustainability: A Nobel Cause.* Cambridge University Press, Cambridge, UK.

Greenhouse Gas Inventories

Policies to tackle climate change rely on the accurate assessment of greenhouse gas (GHG) emissions. However, calculations of GHG emissions contain uncertainty for a variety of reasons such as the availability of sufficient and appropriate data and the techniques to process them. This *Proceedings* brings together the state-of-the-art research and developments in accounting, verifying, and trading GHG emissions with a focus on national GHG emission inventories, bottom-up versus top-down emission analyses, signal processing and detection, verification and compliance, and emission trading schemes.
3rd International Workshop on Uncertainty in Greenhouse Gas Inventories: Proceedings. 22–24 September 2010, Lviv, Ukraine.

Asian Emissions in 2006

The article authors, including IIASA's Zbigniew Klimont, present a new inventory of air pollutant emissions in Asia for 2006. With 61 citations by October 2010 according to the independent citation database SCOPUS, the article is the most cited 2009 paper with an IIASA author. The researchers estimate emissions from all major anthropogenic sources, excluding biomass burning, and also calculate emissions from China, as these dominate the Asia pollutant outflow to the Pacific.
Zhang Q, Streets DG, Carmichael GR, He KB, Huo H, Kannari A, Klimont Z, Park IS, Reddy S, Fu JS, Chen D, Duan L, Lei Y, Wang LT, Yao ZL (2009). Asian emissions in 2006 for the NASA INTEX-B mission. Atmospheric Chemistry and Physics 9(14):5131–5153.

Exploration Dynamics in Evolutionary Games

Evolutionary game theory describes systems where individual success is based on interaction with others. The article's authors, including IIASA's Karl Sigmund, considers a system in which players unconditionally imitate more successful strategies but sometimes also randomly explore the available strategies. The journal article is the second most cited 2009 paper with an IIASA author, with 17 citations by October 2010, according to the independent citation database, SCOPUS.
Traulsen A, Hauert C, De Silva H, Nowak MA, Sigmund K (2009). Exploration dynamics in evolutionary games. *PNAS* 106(3):709–712.

For more IIASA publications, visit IIASA's online publications catalog at www.iiasa.ac.at/Publications

in the news

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MEDIA MATTERS

Where IIASA is making the news

Media coverage over the past six months has focused primarily on IIASA research relating to population change, energy, and climate. IIASA staff have been quoted or referred to in the media of 42 countries, notably Austria, France, Germany, India, the United Kingdom, and the United States. Select items covered by the media include:

Population, aging, and the European Union

▶ IIASA's World Population Program was again very prominent in the international media. Four press releases generated considerable coverage, most notably a release based on an article published in *Science* by Warren Sanderson and Sergei Scherbov on population and aging and the **effect of improved health and productivity on costs to society**. The research provides new tools to more accurately determine the cost of an aging population and to determine more appropriate retirement ages. The study was reported in 40 countries with very broad coverage in Australia, France, Germany, Japan, the United Kingdom, and the United States.

▶ The awarding to Wolfgang Lutz of the Wittgenstein Preis or "Austro Nobel" generated very broad and detailed media coverage in Austria and Germany. This is the **highest science prize in Austria**, and it is the first time it has been awarded to a social scientist.

▶ A press release based on a study published in the *Proceedings of the National Academy of Sciences* and based on research funded through a European Young Investigator's award to Brian O'Neill was reported extensively in the international media. Key countries reporting the story included the United States, Italy, France, China, and India. The study suggests that changes in population, including **aging and urbanization, could significantly affect global emissions of carbon dioxide** over the next 40 years.

▶ A press conference and associated joint press release with the Vienna Institute of Demography on the **European Union population reaching 500 million** received some coverage in Austria and Germany.

Evolution

▶ A *Nature* article lead-authored by Karl Sigmund which demonstrates how self-governing institutions that promote **increased cooperation through sanctions** can evolve spontaneously, attracted the attention of journalists in Austria, Germany, and the United States.

Land use and Forestry

▶ Anatoly Shvidenko is quoted in the Russian press discussing the impact that climate change may have on the **northern forests of Russia and Siberia**.

▶ The application of the **IIASA–FAO developed agro-ecological planning tool** to agricultural planning and food security was reported in the United States and Austria.

▶ A special issue of *Climatic Change* devoted to **uncertainty in greenhouse gas emissions** and lead-edited by Matthias Jonas was covered in several news items, including *New Scientist*.

Energy and climate

▶ An article by Arnulf Grubler and Keywan Riahi published in the inaugural issue of *Carbon Management* was reported primarily in the United States, particularly in the technical press, and was popular with key science blog sites including *The New York Times*, Dot Earth Blog.

▶ An opinion piece by Nebojsa Nakicenovic on **energy and climate** was published in the UK's *Public Service Review* magazine and associated Web site. Prof. Nakicenovic was also quoted in *Scientific American* article on clean energy.

▶ A press release based on work led by Jens Borkens on **greenhouse gas emission levels associated with different forms of travel** received broad coverage in Austria, India, the United States, and Scandinavia, China, and throughout Europe.

In other news an article by IIASA Board of Trustees Chair, Norman Neureiter in *Bridges* magazine entitled "The International Institute for Applied Systems Analysis—A Gem of Science Diplomacy" discusses IIASA history and its contribution to bridging the East–West divide. Visits by the IIASA management team to various member countries to discuss IIASA's new strategic plan has also received some coverage. ■

Spirit of Mohonk

A partnership of actors known for "thinking outside the box," including IIASA's RAV Program, is bringing innovative and creative solutions to bear on some of the greatest social and environmental problems of our time in the Himalayan region

IIASA AND THE HIMALAYA-GANGES REGION
IIASA's Michael Thompson and Nepal's former Minister of Water Resources Dipak Gyawali have been working together for over 25 years to address the ever-worsening environmental degradation of the Himalaya–Ganges region.

The participant list of the international conference on "The Himalaya–Ganges Problem," chaired by Maurice Strong in April 1986 at the Mohonk Mountain House in New York State, is revealing.

Michael Thompson, now *inter multa alia* an IIASA Research Scholar, was on the organizing committee. Dipak Gyawali, one day to become his country's Minister of Water Resources, was a representative of Nepal. For Thompson and Gyawali, the Conference was the beginning of a working partnership that continues to this day and has also stimulated institutional collaborations around the world seeking to address, in Thompson's words: "the rampaging and ever-worsening degradation" of the environment in the Himalaya–Ganges region. Such collaborations assist development agencies in "avoiding the pitfalls of attempting to apply over-generalized policies and broadly conceived panacea in a region characterized by the conference participants as one of the most complex in the world."

This bureaucratic-sounding extract from the 1986 Conference statement was in fact game-changing for development. The Conference itself was an outcome of a 1985 paper co-authored by Thompson, "Uncertainty on a Himalayan Scale," which, he says, caused "merry hell" by challenging the environmental orthodoxy that, for decades, had been the basis of aid to developing countries. As Thompson and Gyawali affirm in a new introduction to the paper republished in 2007 as a book, millions of aid dollars have only turned countries like Nepal into aid junkies, without tackling the real issues that beset them.

The transition away from third-party imposed solutions will be good news for Nepal, but the challenges are huge. In 1994 Gyawali resigned from the board of Nepal's Electricity Authority to join the campaign against Arun-3, an internationally funded US$1.1 billion hydro plant that seemed a done deal between an aid consortium of half a dozen donors and the Nepal Government. The protesters won. Six smaller projects—a much less risky solution for a small developing country—are now in place, producing a third more power than Arun-3 would have done at half the cost and in half the time.

As Minister of Water Resources in 2002/2003, Gyawali initiated reforms in the electricity and irrigation sectors focused on decentralization and promotion of a rural say in governance. Thus, popular engagement, supported by egalitarian actors, is finally beginning to make inroads into some of Nepal's most chronic problems.

Innovative thinking and sophisticated science are also parts of the credo of IIASA's Risk and Vulnerability (RAV) Program, which occupies an internationally recognized niche in reducing countries' vulnerability to the economic impacts of extreme events. In the Himalaya–Ganges, the Institute for Social and Environmental Transition (ISET), a close partner of RAV, is also bringing creative solutions to the region's unusual social and environmental context. Bridging the science–policy–implementation divide across regions and cultures is ISET's main task. ISET seeks "to give all members regardless of gender, ethnicity, or country of origin an equal voice in Institute activities."

It is not surprising to find Dipak Gyawali on the board of ISET and ISET-Nepal, its Katmandu-based sister organization. Forestry and water management, climate vulnerability, flood and drought mitigation, livelihood resilience research, poverty and ecosystem services, climate change, agriculture—are all part of ISET-Nepal's remit, and some of the research is being conducted at IIASA. It is also not surprising to find Michael Thompson and Dipak Gyawali writing a new book, *Development, Climate Change and Clumsiness*, showing the value of taking into account the cultural position of any group or country when making decisions or establishing new policy for them. ■

Further information IIASA's Risk and Vulnerability Program at www.iiasa.ac.at/Research/RAV and the Institute for Social and Environmental Transition at www.i-s-e-t.org

Dr. Michael Thompson and **Dr. Reinhard Mechler** are Research Scholars in IIASA's Risk and Vulnerability Program. **Dipak Gyawali** is the UNESCO/UNU-IAS Visiting Professor of Water and Cultural Diversity at the UN University in Tokyo.

Science Diplomat

International cooperation in science needs places like IIASA, argues Norman Neureiter, Chairman of IIASA's Endowment Fund

It was near midnight on a Saturday in Tokyo, Japan, when Dr. Norman Neureiter took the call from *Options* to talk about IIASA. Despite the hour, Neureiter, touring Asia to promote international science cooperation, was eager to discuss the future of IIASA and the program he considers a major success—the Young Scientists Summer Program (YSSP). "That program alone, with its potential to influence international science cooperation is worth the whole cost of the institute," he says.

As chairman of IIASA's Endowment Fund, Neureiter pays close attention to the place he describes as a "unique international institute," and which he still briefly visits during Endowment Fund and Council meetings. In a recent article for a policy magazine published by the Austrian embassy in Washington, D.C., Neureiter noted: "The East–West orientation of IIASA has turned 90 degrees toward a North–South focus—addressing the great challenges of the 21st century from a politically neutral Austrian location, with scientists from many parts of the world working together." Raising IIASA's profile is important, Neureiter says. "Funding is tight globally and IIASA must build a new image based on the work it is doing right now." He sees his task as chair of the Endowment Fund as growing the Fund to "provide flexibility to support IIASA-sponsored research independent of funding from National Member Organizations or government research contracts."

Neureiter's views have currency because he is one of the most experienced advocates of international science cooperation. He arrived on the international science scene in the mid-1950s as a Fulbright Fellow at the University of Munich, Germany. A PhD organic chemist and fluent in German, Russian, Polish, French, Spanish, and Japanese, Neureiter had a colorful and active early career, serving as a guide and interpreter at the U.S. National Exhibition in Moscow in 1959, teaching Russian and German at the University of Houston, Texas, and serving stints as science attaché for various U.S. embassies in Europe, before moving to the White House Office of Science and Technology as an international affairs advisor in the Nixon Administration.

In 2000 Neureiter came out of retirement after a long career in international marketing to resurrect science programs at the U.S. State Department, and is currently director of the Washington-based Center for Science, Technology and Security Policy at the American Association for the Advancement of Science.

As he travels the globe talking about science, Neureiter hears the argument that it might not be as important these days for scientists to work together at institutes like IIASA. He disagrees.

"IIASA is clear demonstration of how science can be a successful builder of international bridges between countries, "he writes in a national Academies piece. "International cooperation in science and technology . . . can also be a powerful catalyst for improving relations in the social and political worlds." ■

A day in Washington D.C. with Norman Neureiter

9:30 a.m. Arrive in office at AAAS headquarters. Check and respond to messages via e-mail or office phone

10:00–11:00 a.m. Center for Science, Technology, and Security Policy (CSTSP) staff meeting

12:00–1:00 p.m. Lunch with former colleague from the National Science Foundation (NSF)

2:00–3:30 p.m. Meet with the International Office at AAAS on upcoming agenda for Science and Security Meeting in Amman, Jordan

4:00–5:00 p.m. Speaker at the Carnegie Institute

6:00–8:30 p.m. Attend dinner and reception for former colleague at the Civilian Research and Development Foundation (CRDF)

9:00 p.m. Retire for the evening

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- Spend three months in an Austrian castle with around 50 advanced graduate students from over 20 countries and leave with a new global network of research contacts
- Grants available to fully fund participation in the program
- Further information: Contact the program's coordinator at ysspinfo@iiasa.ac.at