Research Plan
2011–2015

I I A SA
International Institute for
Applied Systems Analysis
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IIASA will be the world leader in systems analysis to find solutions to global problems for the benefit of humankind – Research for a Changing World, IIASA Strategic Plan 2011–2020.

IIASA’s new Strategic Plan lays out the overall architecture of the Institute’s research for the next decade (2011–2020). It identifies three global problem areas, which are the major pillars of this architecture: Energy and Climate Change; Food and Water; Poverty and Equity. Research on these three problem areas will be supported by IIASA’s research programs, which have been restructured and aligned for that purpose.

The Strategic Plan states that IIASA’s research should be problem focused and solution oriented. The three global problem areas were strategically selected to include some of the most important policy challenges related to global change. These three problem areas are highly interlinked and many of the most interesting questions lie at their intersection (see Figure 1). The Institute’s challenge is to design integrative analyses that provide insight into global problems, especially those at that intersection, building on the expertise of existing IIASA programs.

Three additional elements of IIASA’s Strategic Plan are activities concerning the drivers of global transformations, advances in systems analysis, and the linkage to policy and governance (see Figure 1). Drivers of global transformations, such as population growth and migration, technology change, and economic development, provide the basis for assessing and evaluating major trends and future scenarios. Systems analysis is the main tool IIASA’s researchers use for modeling and analyses. A key to the future success of systems analysis is the development of advanced models and methods of analysis that use the emerging knowledge in areas such as game theory, behavioral economics and dynamic, adaptive multi-agent modeling, to name only a few advanced areas.

Figure 1. Elements of IIASA’s Strategic Plan 2011–2020.

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Linking research to policy is another key to success. This will require the further development of effective, ongoing relationships with policymakers to ensure that IIASA’s research is responsive to important policy concerns. Understanding the issues related to implementing policy options also raises the important question of governance mechanisms that can facilitate or hinder policy implementation. Combining research excellence and policy interaction is a tall order, but it is crucial to achieve IIASA’s strategic vision to become a world leader in systems analysis.

In order to realize this vision, IIASA researchers worked closely with its National Member Organizations (NMOs) to develop a research plan for the years 2011 to 2015. This research plan was informed by a series of internal and external meetings and workshops during 2010 and 2011. In particular, six workshops were organized by IIASA’s NMOs to provide external inputs from policy makers and the scientific community.

Some of the key recommendations of these workshops were:

- The key to IIASA’s success lies in conducting integrated systems analysis, emphasizing the linkages between problem areas, drivers of global change, methodology innovation, and policy relevance.
- Research should be problem focused and solution oriented, cutting across IIASA’s existing research programs to address real world problems.
- IIASA should continue to strive for innovation and leadership in systems analysis, developing integrated analyses to support international and national policy needs.
- Policy implementation, institutional and governance mechanisms, as well as individual behaviors, should be considered in all research projects.
- IIASA should develop strong, ongoing links with policy makers at global, regional, and national levels drawing on the network of NMOs and their regional partner institutions.
- Capacity building should be an integral part of IIASA’s agenda.

The last point has been stressed by many of IIASA’s new members. In response, we have developed a capacity building plan, which accompanies this research plan. An underlying theme of the capacity building plan is to emphasize the close tie between research and education, as well as between science and practice.

Prior to the development of this research plan, IIASA had 16 separate research programs and special projects. As part of the strategic and research planning process, several of these programs and projects were phased out, some were combined, and some new ones were proposed (see Strategy Implementation Plan, 2010). IIASA has currently eight programs which are aligned with the three global problem areas as shown in Table 1. Two new activities have been added, the Water (WAT) Program and the Policy and Governance Forum (PGF).

All current and new IIASA programs have connections with all three global problem areas, though the emphasis differs. The Energy (ENE) Program and the Mitigation of Air Pollution and Greenhouse Gases (MAG) Program have a primary focus on the interactions between energy production, greenhouse gas (GHG) emissions and climate change, but their research also addresses energy access of the poor and the impacts of energy policies such as biofuels and hydroelectric development on food and water. The Ecosystems Services and Management

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Program, the Evolution and Ecology (EEP) Program and the nascent Water (WAT) Program are studying the systems that are relevant to ensuring food and water security as well as examining the impacts of climate change on the ecosystem and on food and water supplies, particularly in developing countries. The Risk, Policy and Vulnerability (RPV) Program and the World Population (POP) Program conduct research related to poverty and equity, but both cut across the problem areas with interests in vulnerability to disasters and climate change (RPV) and issues of population growth, education and migration in the world’s most vulnerable regions (POP). The Transition to New Technologies (TNT) Program is closely aligned to the Energy and Climate Change Area, but the program scope will expand to include technologies for improving water and food security. Two activities are truly crosscutting in that they support research on all three problem areas: The Advanced Systems Analysis (ASA) Program and the Policy and Governance Forum (PGF). The ASA Program provides methodological support to other programs and research projects. As part of this program, the Advanced Systems Analysis Forum was created with the aim of re-invigorating IIASA’s role as a leader in systems analysis applied to global problems. The PGF is not a full-fledged research program, but a roundtable forum that is designed to facilitate the connections between IIASA researchers and the policy community.

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**Figure 2. Alignment of IIASA’s Research Programs.**

(While all programs contribute to all problem areas, the darker shaded cells indicate areas of emphasis.)
The ultimate challenge is to develop and conduct truly integrative analyses that examine the interlinkages between the three problem areas, using the expertise residing in IIASA’s research programs. IIASA will select leaders for the three problem areas and charge them with developing major crosscutting projects, using the best of systems analysis linked closely to policy making.

The remainder of this research plan is structured accordingly. Part A introduces selected research themes for each of the three global problem areas. Part B develops the themes for the crosscutting and supporting research areas: Drivers of Global Transformations, Advanced Systems Analysis, and Policy and Governance. Part C links the research themes identified in A and B to existing, revised, or new IIASA research programs, explaining their recent accomplishments, present capabilities, and research foci for the immediate future.
Part A

Global Problem Areas
Energy and Climate Change

The Challenges

The provision of adequate energy services is a precondition for socioeconomic development and human wellbeing. Today, however, almost 3 billion people lack access to affordable modern energy services for cooking and some 1.5 billion people lack access to electricity altogether. Inequitable distribution of energy resources has made energy security one of the prime concerns in many parts of the world. Correcting this crucial inequity is complicated by the negative impacts of energy production, transport, processing and end use, most notably the emissions of atmospheric pollutants and greenhouse gases that damage health and property and raise the risks of irreversible climate change. Strategies for global energy provision are therefore inextricably linked to issues of mitigation of emissions of greenhouse gases and pollutants, and adaptation to the climate changes to which fossil fuel use has so massively contributed.

The following policy challenges are of particular concern:

- Lack of access to affordable, reliable, sustainable, and modern energy services hinders approximately one-third of the global population from achieving even minimal living standards. Major global initiatives would be required to achieve universal access during the next decades.

- As the world becomes more integrated and energy import and export dependencies increase, energy security, both of supply and end use have become major threats facing nations, cities, and households, even in the developed world. Further integration of energy systems, such as the emergence of smart grids that combine centralized and decentralized systems with increasing storage of energy, can help reduce these risks.

- Large parts of the world are affected by indoor and regional air pollution from energy production, processing, conversion, transport, and end use. This is not only a serious threat to further development and human wellbeing but a major cause of disease and ill-health, particularly in children and women.

- There is sufficient evidence that climate change is occurring and energy systems are the main anthropogenic causes in the form of emissions of greenhouse gases and other radiatively active substances such as sulfur aerosols and other particulate matter. Decarbonization of energy systems is a priority development goal, from place-specific to global levels, as a crucial element in mitigating the severity of the climate change to which the course of industrialization has committed the world.

- Investments in energy research and development (R&D), both public and private, have declined by a third during the past decades, while investments in modern renewable and fossil energy supply have declined by some 40 and 20 percent, respectively, during 2009 because of the financial crisis. It is estimated that global energy R&D efforts need to increase threefold, while investments should at least double.

- Even with successful mitigation efforts, there will be significant detrimental impacts of climate change. Careful analysis of potential impacts and adaptive response are therefore needed, ranging from improved communication of risks, changing settlement patterns, to flood protection, to changing land use and agriculture, to changing energy and water use as
providing financial support for vulnerable communities to cope with climate change impacts.

To respond to these challenges, transformational changes are required in energy systems, and these need to be integrated with strategies for other adaptations to climate change and globalization. These changes need strong public and private support, and will require new governance models oriented toward clean delivery of energy services in a more sustainable world.

To provide such novel and transformational solutions and guide policies toward more sustainable development paths, research will have to overcome important methodological challenges so that linkages among different temporal, spatial, and institutional dimensions can be better understood. Among these challenges are:

- distilling the near-term characteristics of transformation paths that are necessary for the achievement of long-term targets;
- identifying transformation strategies that are robust against a wide range of development futures;
- developing tools for the analysis of transition strategies at regional, national, and local scales that are consistent with the required global transformation;
- identifying solutions and policy instruments that integrate all important economic sectors and consider interactions and feedbacks among these sectors; and
- overcoming institutional obstacles caused by divergent goals and objectives, misaligned economic incentives, and other barriers to innovation and diffusion.

**Research Themes**

IIASA’s research in the Energy and Climate Change Area falls within five research themes: (i) transformation of the global energy system to achieve a low-carbon world; (ii) reframing the greenhouse gas debate; (iii) investing in energy and R&D; (iv) consumer choice and improving energy efficiency; and (vi) adaptation to climate change.

**Transformation of the Global Energy System to Achieve a Low-carbon World**

Global energy needs will increase. At present, 80 percent of global energy is from fossil sources, which—if unchanged—will lead to catastrophic increases of atmospheric concentrations of greenhouse gases. Transformational change in the energy system is required to achieve two contradictory goals: providing energy services to the half of the humanity without access today and at the same time halving GHG emissions. IIASA research activities will focus on developing strategies that will help accomplish the international community’s long-term objective of stabilizing global mean temperatures at 2°C above pre-industrial levels while allowing for vigorous increases in the energy services required for further human development and wellbeing. Achieving that goal will require policymakers around the world to make informed choices about energy investments and incentives with the goal of reducing the carbon intensity of economic activities by 40 percent over the next two decades. Decarbonization strategies will involve a mix of increasing energy efficiencies, renewable energy sources, nuclear energy, and the use of fossil fuel in conjunction with carbon capture and storage (CCS).
IIASA has a two-pronged modeling approach to decarbonization: the Model for Energy Supply Strategy Alternatives and their General Environmental Impact (MESSAGE) and the Greenhouse gas–Air pollution Interactions and Synergies model (GAINS).

IIASA’s global and regional energy supply scenarios, based on the MESSAGE model, emphasize the dynamics of transformational changes and the requirements of the transitions from the medium to the long term under environmental and climate change constraints. The shorter-term-oriented GAINS model, usually defined at the national scale, focuses on near- and medium-term technology choices to achieve specific air pollutant and greenhouse gas reduction goals. In the proposed planning period, efforts will be made to further develop these two approaches so that they complement each other and thus permit an integrated assessment of climate policies bridging important spatial and temporal scales. This will involve (i) downscaling approaches for the spatially explicit representation of the energy scenario work to selected local and national levels, and (ii) extending the GAINS framework to longer time horizons and scaling it up to the regional and global level.

Another important aspect of this work is to address uncertainty with respect primarily to current and future climate impacts, and also to the effects of policies on public and private investments that will stimulate an energy system transition. IIASA analysis will identify policy approaches that act to reduce the risks of uncertainty rather than amplify it, and identify the relative benefits of those approaches as against those focusing on expected outcomes. Research in this area will complement the work on global transformational changes, concentrating initially on polices for renewable energy diffusion and technology transfer for key regions of the world.

This theme will require coordinated work by the Energy (ENE) and Mitigation of Air Pollution and Greenhouse Gases (MAG) Programs, with contributions from the Ecosystem Services and Management (ESM) Program on carbon cycles and biological CCS options, and from the Risk, Policy and Vulnerability (RPV) Program on policies and approaches for technology diffusion at sub-national scales. The Transition to New Technologies (TNT) Program will provide expertise in technological innovation and diffusion while all scenarios will incorporate the population projections of the World Population (POP) Program.

**Reframing the Greenhouse Gas Reduction Debate**

The current international climate policy discussion about reduction in greenhouse gas emissions does not capture the domestic framing of many countries, which perceive mitigation measures as being in direct conflict with policy objectives like growth and competitiveness. Adaptation is viewed largely in terms of infrastructure needs. This is the case not only for developing countries, but also for highly industrialized nations where public opinion shows a great deal of concern over Earth’s climate in the long run, but little willingness to make near-term sacrifices.

If national climate change policy discussions and international negotiations are to be successful, a policy framework is needed that accommodates the views of all parties involved. A variety of alternative paradigms, such as green growth, sustainable development, and resource-efficient economies are often mentioned as concepts where climate change measures align with other policy priorities.

There is a need for a policy framework and associated analyses that connect climate change policy objectives with other national and global policy objectives so that the ways in which climate mitigation and adaptation measures interact with other policies can be quantified. In other words, a systems framework is required that would permit the integrated assessment of multiple policy priorities and thus help to identify tradeoffs and synergies.
IIASA’s research in this direction includes, for example, the assessment of co-benefits between air pollution and climate mitigation using the GAINS model and the assessment of competition over land for food, fiber, and bioenergy; this work is being carried out by the IIASA Integrated Assessment Framework within the ENE and MAG Programs and by the Global Energy Assessment (GEA). This experience is complemented by the extensive work on agriculture, land use, and forestry in the ESM Program and the climate policy risk work by the RPV Program. It is planned to build on this work to cover a wider range of aspects important for human welfare. The goal of IIASA’s work will be to identify policies that result in quantifiable improvements in current non-climate-related policy priorities and, at the same time, make positive contributions to mitigation of and adaptation to long-term climate change.

This line of energy and climate research will explore inter alia a broad range of climate-related co-benefits of policies to put in place economically beneficial, resource-efficient production systems, increase energy security and access, integrate policies for energy, food, water, biodiversity, and air pollution, and improve approaches to coping with extreme events. It will draw on the expertise of all of the IIASA research programs, and is also likely to be a topic for the Policy and Governance Forum.

**Investing in Energy and R&D**

The energy-supply side poses formidable challenges, partly because energy systems in most countries around the world are aging, and partly because of the long life spans of the facilities and infrastructures being built today. This double challenge of aging systems and lock-in requires a significant ramping up of investment of the order of double the current global energy investments to some $1.5 trillion per year. The challenges on the demand or end-use side are even greater because they involve decisions in which non-energy considerations are dominant, for example, mobility, speed, comfort, and convenience.

In all cases, however, investments in research and development and early technology deployment (RD&D) are essential for achieving technology performance improvements and cost reductions. These developments can be induced by a wide range of policies and market instruments, ranging from feed-in tariffs to taxes and performance standards. Unfortunately, the results of RD&D expenditure inducement are associated with deep uncertainties and a lack of precise knowledge and theory. This is often referred to as the “black-box” of technological change. However, what is known with certainty is that the technologies and systems needed will not be developed and deployed without adequate RD&D funding and, most of all, vigorous investment. IIASA research activities will focus on both the empirical foundations and the policy implications of deploying a wide range of advanced and innovative energy technologies and systems to address these needs. Particular attention will be paid to the global public good aspects of RD&D investments.

Two generic groups of energy-technology RD&D efforts and investments deserve attention. The first is to use less energy through improvements in energy efficiency and conservation (e.g., more fuel-efficient vehicles, super-insulated houses). The second is to deploy alternative technologies and systems. This refers to most alternatives for achieving decarbonization by deploying and diffusing low- or zero-emission technologies (including end-of-pipe emission reduction technologies, such as carbon capture and storage) to replace the currently dominant fossil fuels with their associated high CO2 emissions.

Adequate RD&D is the essential first step in developing new technologies and improving existing ones. It is a necessary but not sufficient condition for a technological innovation to be taken up in the market place. Both the public and the private sectors fund and perform energy technology RD&D; however, systematic data are only available for public sector R&D funding.
Policymakers wish to know how technological change and transformational breakthroughs can be accelerated. Some analyses emphasize economic driving forces, while others argue that public policy and investment interventions are essential. Economic and policy incentives for transformational change tend to fall into two groups: reliance on market forces, shaped by public policy, and traditional public sector R&D support.

There are many obstacles to the diffusion of new technologies, including risk and uncertainties, public concerns and opposition, and inertia of the markets and policy responses. Research at IIASA will examine policies to overcome these obstacles using a real-options framework, innovative financial mechanisms to allow high-return risk-taking behavior, and capacity-building strategies. The analyses will concentrate on investment decisions in the renewable energy sector, including a combination of analytical and numerical modeling approaches combined with empirical evaluation of diverse stakeholders’ perceptions, objectives, and strategies.

It is anticipated that programs contributing to this theme would include TNT, ENE, RPV, whose work on cultural views of risk and fairness is germane to the diffusion of new technologies, and the Advanced Systems Analysis (ASA) Program, which has expertise in investment decision making under uncertainty.

**Consumer Choice and Technological Efficiency in Energy Consumption**

While GHG mitigation potentials in production systems have been studied before, the potential for changes in demand through alternative consumer choices and technological efficiency improvements are less well understood. For instance, energy demand options are represented in aggregated ways in many energy and climate change models (i.e., not taking into account consumer values and choice), and therefore may provide fewer insights for policymakers who want to promote improved end-use efficiency. It is not clear what policy instruments could change behavior and promote technological efficiency improvements that might reduce resource consumption and GHG emissions without compromising human wellbeing. IIASA can constructively address three particular aspects of this problem through collaborative research involving expertise from IIASA programs in all areas: potential GHG reductions due to consumer choices, technological efficiency improvements, and the role of policy instruments.

Demand for food, housing, and mobility, which are determined by consumer choices and, ultimately, preferences account for a large share of GHG emissions. In the short term, it is assumed that preferences will remain more or less fixed. Changes in demand are driven by changes in price, income, and various consumer characteristics like age, education level, and family situation. In the longer term, there is more scope for preference changes, as consumers reevaluate the relative utility of different choices for different reasons. There could also be scope for policy intervention through education, information, regulation, economic incentives etc., which could trigger deeper transformations of societies.

IIASA can address these issues through research that will extend the current analyses of its GAINS, MESSAGE, and GLOBIOM models by improving the treatment of human choice. The overall objective is to develop a quantitative modeling framework of human consumption behavior, and how this could be changed in the medium term to enable a transition to lower energy and land use intensities. The proposed research seeks to determine what factors determine historic and current consumer demand and changes in consumption patterns (notably for food, housing, and mobility) and to estimate quantitative relationships between them. By improving the treatment of the demand side in energy models, this research will provide the foundation for identifying feasible policy interventions to encourage changes in current and future preference structures toward less GHG-intensive consumption patterns.
A second, more limited, line of work within this theme will aim at an improved understanding of the mitigation potential from technological efficiency improvements in the end-use sectors, and in transport, buildings, and food systems. Research will also address policy instruments that could promote efficiency improvements that result in lower life cycle costs but, however, reduce short-term returns to shareholders, as they require higher up-front investments.

As these issues are strongly determined by, inter alia, cultural factors, IIASA will analyze these questions for different countries at different stages of development and for different segments of societies. This work will draw on the models and data from the ENE, MAG, ESM, and RPV programs, as well as on work by TNT and POP. It will require innovations in modeling that should also foster collaborations with ASA.

Adaptation to Climate Change

The effects of climate change are becoming rapidly detectable in numerous ways, from Arctic ice loss to ocean acidification to seasonal climate patterns. The projected changes hold risks for the provision of ecosystem services as profound as the provision of water and food. In addition, global warming may increase the frequency and intensity of extreme weather such as floods, droughts and tropical storms. Efficient, fair, and robust strategies for adaptation to these altered risks are crucial to planning for future decades.

Adaptation to climate change is inherently integrated across all of IIASA’s research programs and, indeed, defines questions that are relevant to all of the Global Problem Areas. An integrative approach to understanding and guiding policy for adaptation to climate change will necessarily include biophysical, economic, and behavioral adaptations to changing circumstances. A thorough adaptation analyses should consider:

- population growth and migration;
- changing energy provision and use;
- changing water storage and use;
- changing land use and agriculture;
- ecosystem response to climate change, in both healthy and marginal environments;
- new trade routes and resource availability, particularly in the Arctic;
- disaster response and recovery, including insurance options, in light of increasing disaster risks; and
- adaptation options in different socioeconomic settings, e.g., rural vs. urban or developed vs. developing world.

Research on adaptation to climate change can draw on existing expertise at IIASA especially in the ESM and RAV Programs and the new Water (WAT) Program. It also offers great opportunities for partnering with NMO scientists and policymakers to define questions and apply analyses to regional and local settings. Population and economic scenarios, drawing on IIASA’s Drivers of Global Transformation work, will be crucial elements of analysis of adaptation options. Likewise, adaptation to climate change will be hugely influenced by the energy strategies adopted in efforts to mitigate those changes – both in terms of the amount of climate change to be expected and the technologies available to help humankind adapt. IIASA’s ENE and TNT will be called upon to contribute expertise there. The understanding of ecosystems, agricultural programs, and land use resident in the ESM Program, as well as the Water Program, will likewise be critical – and analyses of the differing effects of climate change on poor communities vs. wealthy ones should be examined in collaboration with the nascent Poverty and Equity Global Problem Area. Coping with projected changes in disaster and health
risks as a result of climate change will draw on the RPV Program. Finally, it is clear that the complexity of these systems, including behavioral elements that are particularly difficult to model, will require advances in modeling techniques by the ASA Program.

The universality of these adaptation issues also offers exceptional opportunities for partnerships, both with regional organizations attempting to address these issues and with NMOs whose decision makers are trying to cope with climate adaptation on top of the myriad changes associated with economic development and political challenges. A number of national and regional challenges that could be amenable to analysis in IIASA’s neutral setting were proposed at NMO planning workshops. One suggested area of focus was on adaptation strategies for areas of shared water resources in economically underdeveloped areas such as South Asia, Southern Africa and Northern Africa: climate changes will exacerbate existing water shortages in areas where the complexities of demographic, land use, economic, and agricultural challenges are exacerbated by the possibility of violent conflict. Another proposed target area was the Arctic, where IIASA’s neutral status could afford it an honest-broker role related to data and models for adaptation strategies and negotiations in that rapidly changing region.

IIASA’s Strengths

With its history and experience in systems integration and in developing analytical decision-support tools, IIASA is in a strong position to fulfill these objectives. Work in the Energy and Climate Change Area will build on established modeling tools, databases, and large international networks in the energy and climate fields, and also focus on current climate mitigation, adaptation, and governance activities. These include work on informing the understanding of carbon cycling at scales from local to global, modeling and policies related to climate risk, and extensive modeling of ecosystem services.

The global MESSAGE integrated assessment model has in the past been used by IIASA’s Energy Program and others for studying, for example, long-term climate mitigation scenarios for the Intergovernmental Panel on Climate Change (IPCC), energy pathways for the World Energy Council (WEC), and other stakeholder groups and government advisory boards such as the International Gas Union (IGU), the World Bank, and the German Advisory Council on Global Change (WBGU). The MESSAGE framework captures the entire global energy system, from energy extraction, through transformation, to energy use. A high degree of technology detail is also included in the energy submodel and in the macroeconomic and climate submodels.

The GAINS model is a well established tool, developed by IIASA’s Mitigation of Air pollutants and Greenhouse Gases Program to identify cost-effective emission control strategies that meet air quality and greenhouse gas emission targets. GAINS has been applied in the international negotiations of the Convention on Long-range Transboundary Air Pollution and the European Union (EU); it has analyzed mitigation efforts for the climate negotiations under the UN Framework Convention on Climate Change (UNFCCC), and for environmental assessments under the UN Environment Program (UNEP). The GAINS model has been implemented for Europe, China, India, and other Asian countries.

Solutions-oriented research into climate risks, the vulnerability of human systems and ecosystem services, and alternative policy pathways toward successful adaptation has been a strength in several IIASA programs, including the ESM and the RPV Programs. This research has contributed to adaptation policy development at the national scale in countries such as Bangladesh, India, Madagascar, Mozambique and Pakistan, at the regional scale in the Caribbean and Europe, and at the global scale in the context of program development at the United Nations and World Bank, and in the continued negotiation of UNFCCC adaptation instruments.
Food and Water

The Challenges

Increasing global demand for food and freshwater necessitates improved management of the world’s land, water resources, and ecosystems. To provide food and fiber for a world population estimated by IIASA’s World Population Program to be about nine billion in 2050, agricultural production has to increase by 70 percent globally and by 100 percent in developing countries. Equally important is to increase the efficiency of food and water distribution and end use. Food and water security are linked and should be studied together; moreover, each has close links to the Energy and Climate Change and Poverty and Equity Areas.

Human exploitation of land, marine, and freshwater resources has resulted in the degradation of land and vegetation over vast areas, overexploitation of marine resources, depletion of aquifers, and unsustainable restructuring of natural landscapes. These trends will be further aggravated by the impacts of climate change, which are becoming rapidly detectable in numerous ways, from Arctic ice loss through ocean acidification to changing seasonal climate patterns. The changes projected to result from these will jeopardize provision of ecosystem services, even water and food, while global warming could increase the likelihood of extreme weather such as floods, droughts, and tropical storms. Strategies for adaptation to these altered risks are crucial to planning for future decades.

The following policy challenges are of particular concern:

- Use of land and water resources for food production competes with other uses. Facilitating the transition to sustainability requires better understanding, coordination, and management of competing demands on resources and associated ecosystem services.
- Prospects to meet future water demand are limited by the declining possibilities of using additional sources of freshwater and by the decreasing quality of water due to pollution. Freshwater resources are unevenly distributed, and many countries and locations suffer severe water scarcity. Resolving regional conflicts over water supply and utilization is a critical global challenge, and there are several cases where IIASA NMO countries will have to address such issues.
- Forests, wetlands, and lakes play a major role in the subsistence of hundreds of millions of people and are the cornerstones of sustainability in natural landscapes. However, these ecosystems are often not managed in a sustainable way, competition over usage rights is at the core of social and environmental conflicts, and integrated management is rare.
- Seafood is the primary source of animal protein for more than one billion people. Many developing nations and coastal communities depend on fisheries. However, expanding food production from fisheries is hindered by rampant overfishing and changes in marine habitats.

The development of knowledge to support the transition to sustainability of food and water systems requires work to be conducted at multiple spatial scales, the representation of spatial heterogeneity and dependencies, improvements to the accuracy of projections, prediction of ecosystem responses, incorporation of uncertainty, and accounting for both the human dimensions and the socioeconomic determinants and consequences of alternative paths.
In general, research on food, agriculture, fisheries, and ecosystems is moving toward analytical and diagnostic frameworks that help improve food security, protect the environment, manage climate change risks, alleviate chronic poverty, and promote equity. Policy demand is driving the development of integrated tools for assessing links between climate change and development, examining competition between food production, bio-energy, and ecosystem protection, analyzing the resource and health impacts of dietary preferences and changes in food consumption, particularly livestock demand, and valuing water supply and services.

Research Themes

IIASA will pursue a systems approach in which food and water provisioning will be viewed as: (i) embedded in the wider context of land, marine, and ecosystem management, (ii) conditioned by natural resource endowments, and (iii) dependent on socioeconomic developments and sustainable growth.

Research in the Food and Water Area will concentrate on the following four integrative research themes: (i) food security, (ii) water security, (iii) optimizing multiple uses of terrestrial ecosystem services, and (iv) safeguarding sustainable seafood and aquatic ecosystems. There are obvious linkages among these themes, with research on freshwater resources and climate change playing important crosscutting roles. The close links with Poverty and Equity will also be a major feature in all themes. For poor people, adequate access to renewable resources is a major asset. Yet, survival strategies in the face of poverty often amount to stripping this asset by using land, water, and ecosystem resources unsustainably. Ultimately, many problems in the Food and Water Area are rooted in governance issues that arise in the context of common-pool resources.

Food Security

Food provision in developing countries must double in the context of climate change, regional land and water scarcities, growing competition for inputs and resources from non-food uses (including those associated with urbanization), and increasing environmental impacts. How can land-based food resources be sustainably expanded? Research will explore which new technologies, investment strategies, policies, and institutional innovations can provide the greatest benefits for achieving food security and addressing poverty. Simply increasing food production alone will not be sufficient. The main challenge is where and how to grow the additional food so that everyone can receive their share.

Of particular concern are the 49 Least Developed Countries (LDCs), which account for about 15 percent of the population in developing countries and about one-third of undernourished people. In sub-Saharan Africa more than half of the population live in 33 of these LDCs which are home to over 80 percent of Africa’s undernourished. In this context, IIASA research will pay special attention to food provision strategies for LDCs. It will embody an integrated approach to analyzing resource-use impacts, economic consequences of changes in food consumption, in particular protein provision and demand for livestock products. There are obvious similarities between the analysis of demand for food and the analysis described above of demand for energy, and it is hoped that synergies between these two themes can be developed.

On the supply side, in addition to protecting high-potential land already in use, better management of the world’s vast marginal and degraded areas will also help meet increasing demand for food and energy. Options will be investigated for enhancing biomass production without jeopardizing food security, increasing deforestation, or endangering vital ecosystem functions. New databases and decision-support systems will be compiled to conceptualize economically viable, socially responsible, and environmentally beneficial uses of this land.
Impacts of, and responses to, climate change span all the issues addressed by the Food and Water Area and must therefore be tackled as a crosscutting research element and a point of close collaboration with researchers in the Energy and Climate Change Area. The land use sector both contributes to and is affected by climate change. Integrated management approaches, including full greenhouse gas accounting for terrestrial vegetation, together with emerging next-generation dynamic global vegetation models, will provide new insights and response options. IIASA will investigate how managing the biosphere can mitigate climate change and its impacts while preventing increased vulnerability of ecosystems and biospheric carbon stocks, particularly at high latitudes and in tropical regions.

Decision-support systems will be created based on combining spatially-detailed methods and databases. Principal researchers in this theme will come from the Ecosystems and Services and Management (ESM) and Water (WAT) Programs, with the collaboration of researchers in the Advances Systems Analysis (ASA), and Evolution and Ecology (EEP) Programs. The resulting tools will address the need on the part of decision makers to identify effective management strategies for achieving food security, and alleviating water scarcity, in a sustainable manner. The Area Leaders and Program Leaders will work with NMOs to determine local partners in science and policy areas to collaborate with on specific policy needs.

**Integrated Watershed Management**

Improving food security is closely linked with ensuring reliable availability of freshwater resources. The competing water demands of households, industry, and energy production are expected to continue to increase. How can water resources for all competing uses be managed effectively and shared equitably? Addressing this question involves investigation of the prospects of meeting future food demands by improved water management and irrigation expansion, in the context of growing competition with other water uses, increased water scarcity, and climate change. Management of water resources in arid and semi-arid areas to avoid depletion of groundwater reserves is a special problem. Such areas are likely to suffer disproportionately from climate change, necessitating adaptive policies to ensure an adequate long-term water supply. IIASA will develop a generic approach both to improving adaptive policies in response to evolving climate change and to gathering other socioeconomic information about areas currently suffering from water shortages or projected to do so in the future.

Another problem relates to the joint use of water resources by multiple nations. This often requires negotiations between upstream and downstream users of watersheds or river basins. For example, the Himalayas are the source of several watersheds that cross IIASA NMO countries, sometimes several times. IIASA will conduct selected case analyses of agreements negotiated between countries for the common benefit of using a shared watershed.

In addition, and in close coordination with its NMOs, IIASA expects to implement a major model-based integrated watershed management analysis involving land use, agriculture, population, and poverty (and urbanization) aspects, in a cross-border, shared resource context. As part of this exercise, it is planned to create decision-support systems for shared resource management that build on IIASA’s experience of multi-criteria decision modeling, stakeholder involvement, negotiation analysis, and decision analysis.

The issues related to this theme will be the principal responsibility of the WAT Program, which will collaborate closely with ESM, ENE, and MAG in issues related to the intersection of water, land use, energy access, and greenhouse gas emissions. RPV will contribute its expertise related to risk mitigation and participatory, stakeholder-based approaches to resource management. Trans-boundary issues will be a point of focus for the Policy and Governance Forum in close collaboration with NMO researchers.
Managing Multiple Ecosystem Services

In the 21st century, societies are confronted with a panoply of challenges in their efforts to manage the Earth system. These global challenges include basic food, water and energy security problems, as well as control of multi-hazard disasters and new infectious diseases, and range all the way to respecting planetary boundaries of climate systems and basic nutrient cycles. Dealing with such a massive confluence of possible global-scale failures to manage ecosystem service provisioning involves highly complex planning, coordination and international cooperation. These will only progress effectively and efficiently if private and public policies are based on reliable information and policy impact assessments that are grounded on good science. Information paucity and poor understanding of interlocking processes remain obstacles for effective Earth system stewardship. In this decision-making context, collective efforts to manage the Earth system are in danger of being erratic and the result of competing interests, rather than being based on decisions informed by robust science. IIASA's achievements in advanced systems analysis and integrated modeling have been shown to deliver reliable insights on how to manage a set of selected ecosystem services.

The major scientific directions aiming at improved science-based policy making can be represented along three interconnected dimensions: (i) ecosystems; (ii) policy and governance; and (iii) Earth observation.

First, ecosystems research will focus on integrated considerations of the current state and future trajectories of the world’s terrestrial ecosystems and their services. These will include: (i) full verified greenhouse-gas accounting; (ii) spatially distributed models of ecosystem vitality, responses, and feedbacks to climate change; and (iii) assessment of the provisioning of multiple ecosystem services and the management of associated trade-offs and synergies. While this research will mainly build on the existing cluster of IIASA models, ESM will integrate new approaches for stochastic optimization, behavioral economics, and agent-based modeling as well as next-generation vegetation models. Inclusion of issues of water use and water scarcity and linkage to the MESSAGE and GAINS models will be a top priority for the economic models of the ESM integrated modeling cluster, and these research efforts will be coordinated with the emerging WAT Program, ENE, MAG and other in-house collaborators.

Second, research on policy and governance will cover a wide range of management options at different scales, based on the comprehensive application of systems analysis and integrative modeling. In particular, institutional drivers have been found to help clarify a large part of the unexplained variations in the ESM Global Forestry Model, which further underlines the necessity to expand along these lines. But these experiences also indicate that the integration of ideas, from e.g. game theory, will feature prominently on the ESM research agenda. For this theme, close collaboration with other IIASA programs such as ASA and EEP will be absolutely imperative. Next to the methodological work planned for this dimension, its policy component makes it an obvious candidate for early inclusion in the IIASA Policy and Governance Forum.

Third, to facilitate full and responsible use of the increasing number of Earth observation assets, technological developments need to be tracked, and consistency and harmonization among data products have to be improved. However, much of the spatial data used to support research efforts is conflicting, difficult to combine, or has received only limited validation. Research on Earth observations, in collaboration with GEO/GEOSS and national space agencies, will therefore devise new approaches and technologies to collect, harmonize, and verify spatial information, eventually feeding into the integrated model clusters. To this end, new efforts will be explored in the areas of volunteer geography, opening up the vast potential of citizen science (i.e., through development of the Geo-Wiki). Furthermore, ESM will explore generic sequential downscaling and upscaling procedures to address the problem of data scarcity and incompleteness.
Safeguarding Sustainable Seafood and Aquatic Ecosystems

With over one billion people relying on seafood as their primary source of animal protein, living aquatic resources currently supply 15 percent of the world population’s animal protein intake. Many economies and communities, in particular those of developing nations and coastal regions, depend on fisheries. The dire effects of the overfishing of open-access ocean fisheries are already recognized. The impacts of catches on freshwater systems, though shown to be severe, are still underestimated. Research will need to focus on how to secure and expand aquatic food resources without jeopardizing other important services derived from related ecosystems.

Improved assessment of the vulnerabilities of aquatic ecosystems to exploitation and other anthropogenic impacts is vital. The limited capacity of conventional statistical models (still the mainstay of such assessments worldwide) to describe regime shifts and other surprising changes in the dynamics of living resources (“greenlashes”) underscores the importance of process-based modeling and management. In the spirit of the much-touted, but as yet little practiced, ecosystem approach to fisheries management, such process-based models will be developed and applied to case studies.

Aquatic ecosystems are governed by strong and diverse feedbacks, including multiple actors beyond the biological system. Consequently, the socioeconomic dimensions of resource management need to be incorporated into integrated assessments of harvest-control rules. To move toward this goal, aquatic food-provisioning systems must be recognized as comprising at least four subsystems that are connected in a powerful feedback loop: (i) the natural system; (ii) the resulting ecosystem services; (iii) the management system, which establishes the regulatory regime in which fishing takes place; and (iv) the socioeconomic system. IIASA research will address the missing interdisciplinary links in contemporary fisheries science and develop tools for integrated bio-socioeconomic assessments of aquatic food-provisioning systems as a basis for holistic management advice. In doing this, there are clear links to ASA, with its expertise in game theory, as well as to policy and governance.

Recent years have witnessed growing awareness that the harvesting of living resources can induce unexpected, and often undesirable, evolutionary changes. With harvest mortalities exceeding natural mortalities by as much as 400 percent, adaptive responses of wild populations to the altered selective environment caused by their exploitation are inevitable. These evolutionary dimensions of harvesting have been overlooked for decades, and a new generation of resource scientists and managers need new scientific tools to cope with the opportunities and threats of harvest-induced evolution. Accordingly, IIASA research will develop a toolbox for evolutionary impact assessment (EvoIA) as a structured approach to assessing the evolutionary consequences of harvesting and evaluating the merits of alternative management options.

Research under this theme will be carried out principally by the EEP Program, with cooperation from the ESM Program. There are also links to the work on food demand and consumption patterns described above, as well as to the Poverty and Equity Area to the extent that some overfishing arises from unsustainable survival strategies. Consultation with researchers from the Drivers of Global Transformations Area, the Advanced Systems Analysis Program and the Policy and Governance Forum will also be undertaken as appropriate.

IIASA’s Strengths

IIASA has several programs that have experience with the food and water problem area. The Ecosystems Services and Management Program has significant strengths in agriculture, forestry and ecosystems studies. This program serves many of the modeling and analysis needs in the area of food security and ecosystems services. A new Water Program will be created to support
work on water security and to integrate water more tightly into the analysis cycle. The Evolution and Ecology Program has, for many years, examined fisheries issues related to food provision from aquatic systems.

These programs have jointly produced many models that have been used world-wide. They include most notably agricultural models (GAEZ and GEPIC), economic models (BLS, GLOBIOM), forestry models (G4M), among others. The challenge is to develop an integrated set of models to address the research questions outlined above.

IIASA has also been at the forefront of the development of new applications of adaptive dynamics evolutionary approaches, integrated approaches for assessing the stabilizing role of forests and agro-forestry in natural landscapes, and developing a range of data and decision-support resources. Among the latter are: (i) decision-support and data-warehouse methodologies; (ii) algorithms for data harmonization and probabilistic spatial downscaling; (iii) an integrated land information system, including data layers of land resources, water resources, land cover and land use; (iv) a multisensor remote-sensing concept; (v) harmonization of mutual constraints among data; and (vi) an approach to policy-model-data fusion that supports international climate policy development.
Poverty and Equity

The Challenges

Meeting at Monterrey in Mexico in 1999, the world’s leaders embarked on an unprecedented effort to address global poverty. Expressing dissatisfaction with previous efforts, they called, first, for leaders in poor countries to adopt a broad, holistic, and inclusive approach to poverty reduction; one characterized by genuine national commitment, ownership and stakeholder dialogue. In exchange, leaders of the world’s wealthy countries committed themselves to a more user-friendly and effective approach to aid; one stressing predictability, streamlining and harmonizing conditions and procedures, and relying on national institutions and systems whenever possible; commitments made concrete in the Paris Declaration and Accra Agenda for Action (2008). The new approach emphasizes results-based management and objectively verifiable indicators, especially as expressed in the Millennium Development Goals (MDGs) and associated targets.

Results to date have been mixed:

- While there has been substantial progress in reducing income poverty, much of this is due to hyper-rapid economic growth in a few large countries, especially China, India and Brazil. Furthermore, rapid growth has brought with it new challenges, including pollution, a widening income gap and social conflict.
- It is estimated that 1.2 billion people are still estimated to earn less than one US dollar per day. At the same time, understanding of poverty has advanced beyond narrow metrics based on income or consumption to include capabilities, assets and livelihoods. Broader conceptions of poverty link it not only to material deprivation but also to access, entitlements, social networks, voice and empowerment. Life-cycle risk-based approaches to poverty, stressing complex dynamics and interactions, are increasingly favored.
- MDGs related to health (reducing maternal and child mortality) have proven difficult to meet, in large part because the health sector is synergistically linked to so many other sectors (education, water and sanitation, housing, income, etc.). Progress has been made against the diseases of poverty identified in the MDGs (HIV/AIDS, TB, and malaria). However, the AIDS epidemic continues to impose staggering costs and distortions on health systems, multiple-drug resistant TB is rising, and anti-malarial resistance problems are being encountered in some regions.
- In a number of countries, progress is being made on MDGs related to basic education. However, the lack of labor market opportunities is leading to unemployment even in more highly educated poor countries. In some countries, where efforts such as Education for All have increased the quantity of education, its quality continues to be problematic. In other countries limited progress has been made toward universal primary education.
- MDGs related to gender and the environment have proven vague and difficult to address.
- Urbanization continues to outstrip the ability to create infrastructure needed to absorb burgeoning populations while improving slum conditions. The face of poverty is increasingly an urban one, while traditional development approaches continue to address mostly rural needs. Rural poverty is increasingly concentrated among hard-to-reach, high marginal cost populations, often belonging to ethnic and linguistic minority groups located in geographically isolated areas.
In many African countries population growth still continues to be fast due to very high fertility, making the expansion of school enrollment, health care facilities, and other services an uphill battle.

The link between conflict and poverty remains as tight as ever.

The new global development partnership shows promise, but has been a mixed success. Evaluations of efforts to streamline and harmonize aid in order to make it more effective have indicated only very slow progress. Aid flows are still lower than required (for example, they are dwarfed by migrant remittances), although it is perhaps debatable whether the absorptive capacity exists to deal with targeted resources. The traditional humanitarian motivation for aid has been called into question both by the increased connection between in aid and resources and growing reliance on the global public good rationale for aid.

Issues of equity extend beyond poverty. Globalization and technological change have created winners and losers; climate change, while it may be said to adversely affect all, is likely to affect some much more negatively than others. Understanding equity means understanding how societies’ goods and “bads” are distributed, as well as how drivers of global change affect this distribution.

Poverty reduction involves many players working together at the national, regional, and international levels. The variables to be addressed are many. Demography, education, technology development and adoption, investments and stock accumulation, resource depletion and degradation, and ecosystem responses all interact and have their own specific dynamic features.

Research is needed not only into measurement issues and the multidimensional drivers of poverty and inequity but also into how and under what circumstances policies achieve development goals. One of IIASA’s primary roles in the study of poverty and equity will be to apply a systems analysis approach, building on extensive prior work with driving forces, and incorporating feasible policy choices. Systems analysis is needed to carry out spatially detailed modeling of multiple actors in diverse social and environmental conditions in combination with accounting for physical and financial flows across multiple scales and achieving consistency of representation through global coverage and systems closure. The model-based systems approach allows for identification of synergies, feedbacks, and leverage points for effective policy. The emphasis will be on finding robust and politically feasible policy responses that are consistent with a global transition to sustainability under conditions of climate change and the growing fragility of natural systems.

Paradoxically, most poor people do not live in low-income countries, but in middle-income countries; a handful live in high-income countries, as well. This underscores that special attention needs to be given to equity. Much, if not most, of IIASA’s proposed work in the Food and Water and Energy and Climate Change Areas addresses problems that can only be resolved by confronting competing normative views of fairness.

**Research Themes**

**Integrated and Multi-dimensional Modeling of Poverty**

A theme that repeatedly emerged during the research planning process was the complex and integrative nature of poverty, cutting across income, health and education, the environment, access to energy and other resources including water, and exposure to natural catastrophic risk, etc. IIASA’s expertise in dynamic systems, agent-based modeling and in multi-criteria decision
analysis can be used to develop advanced tools to examine the dynamics of poverty in a multi-sector context and to study policies to overcome it. An important link of this work to inequity is the study of strategies that reduce poverty by stimulating growth without increasing inequalities. Another link is the study of routes to economic growth that minimize increases in the environmental or climate change burden.

Specific topics that link poverty and equity to research in IIASA’s current and planned programs are:

- Energy poverty: how to improve the energy access of the poor and simultaneously improve their environment and health and reduce greenhouse gas emissions;
- Poverty and ecosystems: how to break the cycle of poverty and ecosystems degradation;
- Poverty, inequity and education: how to reduce poverty and inequality through education;
- Poverty and vulnerability to disasters: how to reduce susceptibility of the most vulnerable and poor people of the world to disaster; and
- Equity and public good: how to design regulatory environments to foster equitable access to and sustainable use of public goods and common-pool resources.

In pursuing this research theme, IIASA will build on its strong tradition in all aspects of natural resource and environmental economics (including subjects often considered under this rubric, such as natural catastrophic risk and infectious disease). Programs likely to be involved are ESM (access to renewable resources, food security) WAT (water and sanitation), POP (education and poverty; employment, labor market, urbanization, and migration projections and studies), RPV (catastrophic risk, cultural views of equity), ENE (access to clean energy), MAG (exposure to air pollution), and EEP (governance design and evolution). Close collaboration is expected with ASA and PGF.

**Wellbeing, Development and Equity**

Traditional welfare economics emphasizes the value of national economic growth and associated individual income and wealth as major indicators of wellbeing. This emphasis on the economic aspects of wellbeing has been criticized in the past decade. Several streams of research are coming together, encouraging a research agenda that attempts to develop a more meaningful and comprehensive set of measures of wellbeing. This includes work conducted by the UN on the Millennium Development Goals, work on human development indices, as well as recent work by behavioral economists on indicators of well being other than economic wealth.

IIASA proposes an exploration of these streams of research to develop a consistent set of measures of wellbeing. IIASA has experience in this area through its multicriteria decision making research. This research theme brings together work being done by the UN and the behavioral economics research on well-being to develop a set measures that IIASA can use in its integrated assessment of policies in the areas of energy and climate change, food and water, and poverty and equity. As such, the entire range of IIASA research programs would be involved in designing indices in their area of work.

Much research in this area revolves around distribution, equity, fairness and wellbeing. There is a strong research tradition supporting the hypothesis that any increase in inequality is welfare-negative for all agents; that is, if the rich get much richer and the poor get somewhat richer, the welfare of both rich and poor is impaired. Yet, there are alternative views and no consensus. Demography and education are also related to wellbeing: there is evidence that education is negatively correlated with self-assessed wellbeing, but that self-assessed wellbeing rises with age.
Poverty Traps

The issue of poverty traps continues to be a major theme of global development efforts and research. Poverty traps arise in a wide variety of contexts where feedback loops and self-reinforcing mechanisms limit the capacity of the poor to emerge from impoverished circumstances. Many of these situations have evident links to IIASA’s research strengths, making this a natural cross-cutting research theme. IIASA has particular expertise applicable to poverty traps in the contexts of:

• Renewable resources: Impoverished populations and families, forced into destructive survival strategies, often mine their endowment of resources, including soil, water and biodiversity. In its work on ecosystems management, IIASA’s ESM program is well-placed to examine these issues, as is the EEP program in the context of marine resource management.

• Education: Major economic shocks or other crises often entail the withdrawal of individuals, and especially young women, from school, as was the case following the 1997 Asian economic crisis. By impeding female empowerment and limiting the accumulation of human capital, which has been shown to be a critical element of development, this survival strategy perpetuates and reinforces poverty. IIASA’s POP Program has an extensive portfolio of research on the projection and effects of human capital formation, which will be applied to the problem of education-related poverty traps.

• Health: Research in Asia has shown that catastrophic health expenditure, conventionally defined as expenditure exceeding 25 percent of household income, is a major impoverishing event in countries such as China, Vietnam and India. Catastrophic health events force families to sell off assets and borrow money, often ensnaring them in a poverty trap from which they have little hope of escape. Ongoing IIASA projects on the dynamics of catastrophic risk management and on complex systems interacting to affect human health and wellbeing, especially in the context of rapid urbanization, will take account of such potential traps.

• Natural Disasters: There is substantial interest in the effects of systemic disaster risk on incomes and livelihoods of households and farmers, particularly those in developing countries. An important question is whether and how weather extremes may trap people in poverty. Ongoing research in the RPV Program focuses on assessing the type and scale of poverty traps in developing countries and identifying mechanisms that can help overcome low level equilibria.

IIASA research in this theme will focus on identifying and evaluating effective policy solutions for well-defined poverty traps in all of these and other areas, as well as on identifying the common factors contributing to the persistence of poverty.

IIASA’s Strengths

While the Poverty and Equity Area is often referred to as the “new” area, IIASA has substantial research experience on issues related to poverty and equity. Subjects that have been studied at IIASA include low levels of education, weak social protection systems, unsatisfied energy demand, food and water insecurities, natural disasters and catastrophic risk, infectious disease and climate change. IIASA can build on its traditional expertise in matters of natural resources, the environment, risk management, and adaptation in the context of global change. Above all, IIASA has strength in using systems analysis to identify better responses to poverty and equity challenges, and can call upon its existing expertise in integrated assessment in other fields.
Through its senior scientists, IIASA has been linked to policy advisory and evaluation work with a broad number of international agencies, including bilateral agencies, UN organizations, and the European Union. The Policy and Governance Forum described below will offer the opportunity to exploit these ties further.

In embarking on research in this area, IIASA is strengthened by the expertise of its National Member Organizations in developing countries. This gives the Institute access to, among other things, research networks, unique data sources, a pool of graduate students, and opportunities for research exchange and visits. However, it also places greater emphasis than in the past on capacity building activities. Some of these, such as the IIASA Young Scientists Summer Program (YSSP) and Post-doctoral Program, are discussed elsewhere in this Plan. More generally, though, what is needed is a closer working relationship revolving around joint research and publication initiatives between IIASA researchers and researchers in the field.

**Summary**

Table 1 shows a summary of this section in terms of areas, themes, and how IIASA’s research programs can contribute to them.

**Table 1. Summary of Areas, Themes, and Programs**

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<th>Global Problem Areas</th>
<th>Crosscutting Research Themes</th>
<th>Participating Programs</th>
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<td><strong>Energy and Climate Change</strong></td>
<td>Transformation of the global energy system to achieve a low-carbon world</td>
<td>ENE (energy supply and demand scenarios)</td>
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<td>TNT (Diffusion of energy technologies)</td>
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<td>MAG (air pollution synergies)</td>
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<td>POP (population growth)</td>
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<td>Reframing the greenhouse gas reduction debate</td>
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<td>Global Problem Areas</td>
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<td>POP (education, age and well being)</td>
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<td>ASA (multi-criteria analysis)</td>
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<td>Poverty traps</td>
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Part B

Cross-cutting Research
Drivers of Global Transformations

Introduction

The world continues to undergo profound changes. Some of these can be positively influenced and some need to accelerate as the transition toward more sustainable development takes place. There are three key drivers of these changes: people, technologies, and economic growth, which today is practically synonymous with globalization. People are the agents of change, and technology is the toolbox that they use. Together, they produce economic growth, which, as seen by the recent growth in the emerging economies, changes the global economic and strategic landscapes. IIASA has currently two strong programs that contribute to understanding these drivers of global transformations: The World Population (POP) Program and the Transition to New Technologies (TNT) Program. This research plan also foresees the development of a project or eventual program on sustainable economic growth.

Changes in population, technology and economy occur relatively slowly in most countries. Both at the demographic level and at the individual level changes in behavior over a person’s life cycle tend to be gradual. It must also be observed that despite rapid introduction of new technologies into markets, their integration into everyday practice (diffusion) can often be slow because of inertia and technological “lock-in” effects. Like population dynamics, the rate of change of large technological systems (as opposed to individual technologies) could be one of the “slow” variables of societal systems. Economic growth lags behind the development of the educational skills of the population, internal and foreign capital investment, and technological diffusion. As the example of today’s middle-income countries shows, this growth is often accompanied by environmental degradation and increasing inequalities.

These three drivers of change and their interactions have to be understood and integrated into the research in the three global problem areas of IIASA: Energy and Climate Change, Food and Water, and Poverty and Equity. In all three areas the solutions for securing pathways toward sustainable development can only be found if likely future trends in these three main drivers, their constraints, and their opportunities, are taken into account.

While the drivers of the three fundamental components of demographic change – fertility, mortality and migration – continue to be the subject of debate and differing views, there is little disagreement on the preferred approach to population projection. IIASA is a world leader in cohort-component, multi-state approaches to population projection, including the incorporation of uncertainty. For IIASA, the research challenge is how better to embed such projections in its work on Energy and Climate Change, Food and Water, and Poverty and Equity. One part of the challenge is to continue methodology development while better applying the tools already available into IIASA’s work across the Institute. Yet, this will require IIASA to expand its activities in the areas of urbanization and migration, taking it into areas where large issues of determinants and consequences remain unanswered. In the first case, definitional issues, as well, need to be addressed and much better data are needed (for example, the concept of “core region,” a region where human and physical capital are disproportionately concentrated may be more apposite than the legal concept of a city). Urbanization must be placed in the context of sustainability of food and water systems; in addition, links with energy use and climate change need to be taken into account. Understanding migration requires an understanding of economic and non-economic determinants, an area new to the Institute.
Like demography, technology crosscuts almost every topic addressed by IIASA’s three research areas. The core challenge of technology research at IIASA will be to consider technology as a man-made resource and as an essential element of a transition toward sustainability. Technologies do not emerge randomly, but are created and used by humans, while the process of technological change is embedded in the incentive structures and resources that societies put in place. From this perspective, all technological change is induced. And yet, large-scale technology systems by themselves can also constitute substantial constraints: large sunk investments in R&D, a formidable degree of complexity and interrelatedness among many individual technologies that can rarely be changed simultaneously, and deep innovation uncertainty in terms not only of technical and economic feasibility but also of social acceptability; moreover, potential (often unanticipated) environmental impacts and cultural attitudes can act as important barriers to rapid and substantial technological changes. The challenge is to better understand what incentive structures are likely to give rise to technological innovations and diffusion to support the transition to sustainability. Yet, as is increasingly clear, technology is a double-edged sword; technologies for genetic engineered foods, life extension and reproductive technologies, to take only three examples, are contested by the public in many countries due to risk perceptions as well as ethical and moral concerns. The Internet has increased connectivity yet, some might argue, reduced connectedness. Perhaps the ultimate challenge is to understand better the relationship between technology and human wellbeing, sustainability included.

In economic growth the challenges are to understand the drivers of growth and to develop policy solutions that support sustainable growth, while at the same time avoiding environmental degradation and inequalities. Many developing economies are struggling with these challenges. Most of those with rapid rates of growth depend on coal-dominated energy systems that result in multiple negative environmental externalities. In their search for solutions they ask for “green growth,” “inclusive growth,” or “sustainable growth,” which are all similar labels for an environmentally and socially sustainable growth path. Often, the green growth is associated with decarbonization as a kind of “proxy” for transformational economic changes toward sustainability. Another important challenge is to understand the impact of economic growth and international trade on globalization and to develop national and international policies that enhance the benefits of globalization while avoiding its risks.

Research Themes

Following are four research themes for IIASA’s research on drivers of global transformations. These either focus on interlinked drivers or on the linkage of the drivers with IIASA’s three global problem areas. With population and technology research already well established at IIASA, the area of economic growth offers an opportunity to develop an expanded niche in this area.

Understanding Population-Level Diffusion of New Technologies and Accelerating Technology Diffusion

Understanding the mechanisms by which and the conditions under which innovations in behavior and the use of new technologies spread among the general population is critical to translating IIASA research in a range of fields into effective policy. For behavioral innovations at the level of entire societies, in which increasing segments of the population adopt and use new technologies (such as new modes of transportation, new communication technologies such as cell phones, or new consumer products), the preconditions and mechanisms of change depend largely on prevailing attitudes and their development over time and across cohorts, including the changing responses of the general population to new technologies as their age and education distributions evolve.
In examining technological and behavioral innovations at the population level, IIASA is in a unique position to draw on two distinguished but so far separate research traditions—multi-state population projection and technology diffusion—that can be “married” to produce something entirely new. Demographic, social and institutional variables have been identified as important drivers in explaining rates of diffusion of new technologies or the lack thereof. And yet, while past research has provided valuable insights, most analyses have to date treated these variables at the aggregate macro-economic (e.g., social-institutional variables in new economic growth models) and macro-demographic levels (e.g., using total or urban population levels as a proxy for estimating potential adopter populations). Novel approaches that explicitly incorporate the evolving heterogeneity of socio-demographic developments and that can lead to heterogeneous rates of technology adoption and diffusion are needed. IIASA has twin core competences in demographics and technology diffusion studies, and a successful track record in blending the two. In fact, one of the first models to use cohort-specific population dynamics in developing alternative scenarios of "green mobility" was developed at IIASA well over a decade ago.

An important corollary to understanding the mechanisms of technological spread at the level of individuals and societies is the development of policy mechanisms to speed the diffusion of needed innovations. Technologies that improve resource efficiency, substitute more abundant material resources for scarce or exchange clean production processes and consumption patterns for polluting ones are among those that will need to be developed and diffused to address the three global problem areas on IIASA’s research agenda. Methods of influencing and accelerating technology transformations toward more sustainable futures need to be elaborated. Much of IIASA’s work on drivers will focus on this policy-relevant research area of “transformation management.”

In fact, many current policies are directed at inducing further technological and institutional changes, more rapid economic development, or accelerated demographic transitions. Yet, in many cases, we do not understand, nor are we able to predict, the exact nature of system responses to policies for change (e.g., to what extent research and development drive technological change, family policies influence human fertility, or monetary and fiscal policies impact economic growth rates) or inducement mechanisms, themselves often surrounded by deep uncertainties. This new research will not duplicate the large efforts put into studying national “innovation capacities” or technology effectiveness and demographic or economic policies, but rather focus on understanding the fundamental drivers of change, how they can be influenced or induced, and the possibility of integrating their synergetic effects.

Research in this area will include development of theoretical approaches to explaining rates of change in technology systems, comparative empirical case studies of technology policies, and development of models to describe the evolution of technology systems combining agent-based and game-theoretic approaches. These models will be used to simulate the impacts of alternative technology policy regimes based on the theoretical approaches devised and on empirical case studies.

Research on the dynamics and policies of technology diffusion will be complemented by collaborative research in the three global problem areas, in particular on:

- Interactions between demographics and technology diffusion (as described above) with a proposed study on how to overcome the digital divide as an important connection with the Poverty and Equity Area.
- Introducing agents of change and spatial heterogeneity as drivers of technology adoption in integrated assessment models as important determinants of climate change mitigation costs and dynamics; this will build on past and ongoing successful collaboration in the energy/climate change and technology research spheres at IIASA.
• Assessment of technological solutions for ensuring water supply for agriculture, a collaborative effort with the Food and Water Area. Mechanical energy is essential for water pumping from substance farming through to the most productive farming practices. At the same time, technologies for enhancing water-fed agriculture and desalination in more arid areas are of central concern in strategies to feed the world.

Interactions between Population, Education, Poverty and Equity

Much has been written about the “Vicious Circle” (or “Demographic or Poverty Trap”) in which rapid population growth inhibits the development that would be necessary to bring down fertility rates and hence population growth, often in conjunction with environmental degradation (such as deforestation) resulting from both high population growth and poverty. There have also been many historical instances in which this vicious circle has been broken, fertility rates have started to decline, and economic growth has picked up. The dominant explanation for this association between fertility decline and economic growth is the “demographic dividend,” the reasoning that a decline in demographic dependency (caused by a reduction in the birth rate) results in a higher proportion of the total population being of working age and leading, as a consequence, to higher per capita income. But what triggers the fertility decline? Here evidence from successful countries shows that it was the combination of two factors, basic female education and availability of family planning services, both low-cost investments that can even be implemented by poor countries, if the right priorities are set.

The theoretical and empirical analysis of these interactions is a crosscutting activity that involves many groups at IIASA, primarily those concerned with poverty and equity, but also those that deal with relevant environmental aspects, such as land, water and energy. In addition to the population and educational aspects being covered by the World Population (POP) Program, the analysis is related to economic growth and equity issues. A recent IIASA study (published in Science 2008) showed that it is an equitable distribution of education (broad-based primary and junior secondary education) rather than the often favored elitist higher education which is the major prerequisite for economic growth that is strong enough to push poor countries out of poverty.

Urbanization and Migration

Urbanization and migration are major driving force and a cross-cutting issue that affects all analyses of IIASA’s research on global problems areas. While recognizing the difficulties in studying urbanization and migration trends, many participants in IIASA’s external workshops have stressed that there is an urgent need for new models, tools and data analyses in this area. Some issues in developing a study plan on urbanization and migration ar

• Urbanization raises difficult conceptual issues of definition, measurement, etc., which will need to be addressed in IIASA’s work. In particular, ways need to be found to address social and spatial heterogeneity simultaneously.

• IIASA’s work should build on its status as a center of excellence for demographic projections, based primarily on the methods of multi-state demography that were developed at IIASA in the 1970s, to facilitate the incorporation of urbanization work into all IIASA research activities.

• Internal as well as international migration will be studied in a comprehensive way which does not only consider conventional pull and push factors but also possible effects of climate change on migration. Links between poverty and rural-urban migration will be considered, but also the important subject of how international remittances act as a buffer against poverty.
• Urbanization work should be incorporated into multiple areas, e.g., water demand, food and land use (including the conversion of farmland to non-farm use), diffusion of technologies, the need for health services and impact on disease patterns, shifting energy demand, etc.

The effort on urbanization and migration will begin with methodology development. Clearly, as space-based dimension is needed to enhance traditional population models, similar to adding a spatial dimension to traditional sectoral input-output models by adding transportation networks. IIASA has made major improvements in population projections by adding non-traditional features like probabilistic forecasting to cohort models and by adding more detailed studies of education and its impacts into population modeling. Adding a spatial dimension seems like a very worth-while next challenge.

**Sustainable Growth**

Several of the new members of IIASA are experiencing rapid economic growth. Recognizing that economic growth comes with unintended side effects, such as environmental degradation and growing income inequalities, these countries are looking for policy solutions to reduce the negative impacts of growth while maintaining a long-term path to a sustainably developing economy. The Republic of Korea calls this a path to “green growth,” India shows its concern for avoiding inequalities by emphasizing “inclusive growth,” and China wants to reduce wastes and pollution by advocating “no waste growth.” No matter what the label, the intention is clear: while economic development is a key objective, it should be managed in a way that avoids the negative side effects already experienced by many industrialized countries and now also being experienced by the emerging economies.

While the interest in sustainable growth is similar in the emerging economies, some of the drivers of growth and the institutional and cultural environment are very different. For example, in contrast to China and Korea, India is still experiencing significant population growth, which complicates the process of managing growth. It is important to study options for managing sustainable economic growth in the context of these differences in drivers as well as in institutional and cultural aspects.

IIASA has significant research skills that can contribute to studying sustainable economic development. One important area is the study of the co-benefits of pollution control in terms of health and climate change. Another interesting area is the exploration of new technologies for environmentally compatible economic growth, like carbon capture and storage, renewable energy, or nuclear technologies. Yet another area is the study of energy paths that lead to a sustainable high-efficiency, low-carbon energy economy. An overarching question is whether advancing green technologies can improve a country’s economic competitiveness and spur additional growth and employment.

**IIASA's Strengths**

IIASA has pioneered the development of demographic methods and applications that are structured according to dimensions beyond the usual parameters of age and sex. In particular, the changing distribution of populations by place of residence, level of educational attainment, and other properties such as religion can be described using the tools of multi-state population dynamics, developed at IIASA. As population structures have great inertia and change only slowly and often in a predictable manner, such population projections provide one of the most reliable analytical handles for projections of social change over several decades. IIASA population projections also include comprehensive assessments of populations’ three main drivers: fertility, mortality and migration.
IIASA is best positioned to study these interactions between age structure and other phenomena in a comprehensive manner because of its unique reconstructed data set and projections for distributions of the population by educational attainment by age and sex for over 120 countries and its history of several in-depth population-development-environment (PDE) case studies such as those on Mauritius, Yucatan, Namibia, BOTSWANA and Mozambique. While several other groups are studying the “demographic dividend” and “vicious circles” dynamics, IIASA was the first to integrate education and equity issues into the model. But much more comprehensive empirical and theoretical work in this field is needed at the cross-national as well as sub-national level in order to gain a deeper understanding of these complex but essential interactions.

In the area of technology, the first models to incorporate uncertain increasing returns to technology adoption and of empirical case studies underlying these phenomena were developed at IIASA. The resulting insights for technology policy, in particular the need for early and sustained, though cautious and gradual, experimentation have received wide recognition. More recently, the methodological framework for technology studies has been enlarged by a novel approach combining agent-based modeling and evolutionary algorithms in the study of technological complexity.

IIASA has recently engaged in some exploratory work on economic growth, primarily focused on the interaction between technology and growth and various forms of mathematical growth theory. However, it is fair to say that IIASA has not yet found its niche among the major research centers studying economic growth. The concept of “sustainable development” or “green growth” offers an opportunity to develop in partnership with IIASA’s NMOs, several of which are interested in this class of topics related to economic growth and where there are opportunities for partnerships and networks that can underpin an effort in this area. There is also an opportunity to couple the economic growth work at IIASA to the Poverty and Equity Area with an emphasis on growth policies that avoid increasing income inequalities.
Advanced Systems Analysis

Introduction

Systems analysis utilizes the analytical techniques of mathematical models to analyze complex systems with an emphasis on holistic and integrated problem formulation and an interdisciplinary approach to finding solutions based on the best science.

IIASA’s approach to systems analysis stresses the development of methods that allow integrative and multidisciplinary approaches to these problems, including decision analysis, dynamic adaptive systems, stochastic optimization, risk and uncertainty, and multi-criteria analysis. The objectives of IIASA methodological activities are to (i) advance the mathematics of systems analysis and (ii) apply advanced methods of systems analysis to IIASA’s applied research.

The challenge for IIASA now is to develop new and advanced methods, models and tools of systems analysis inspired by and in partnership with IIASA’s applied research activities, thus reinvigorating IIASA’s leadership in systems analysis relevant to the critical problems facing the world.

To meet the challenges of developing advanced models and methods while being relevant to applied work at IIASA, this research plan defines the following changes in IIASA’s methodological research organization:

- Creation of a new Advanced Systems Analysis (ASA) Program through a merger of the Dynamic Systems (DYN) Program and the Integrated Modeling Environment Project (IME). The ASA Program will be at the center of three main crosscutting research topics: Advances in Modeling Dynamical Systems; Extreme Events; Systemic Risks and Robust Solutions; and Integrated Modeling and Decision Support.
- Creation of a new Advanced Systems Analysis Forum, a roundtable of all IIASA researchers and external experts who are interested in advancing modeling, simulation and analysis to improve the applied research conducted at IIASA. This roundtable will also support the innovations theme of the ASA Program.

IIASA’s ASA research will continue to be strengthened by IIASA’s other research programs. The ASA framework will facilitate, coordinate, and cross-fertilize all such research at IIASA. Following are descriptions of IIASA’s ASA research themes.

Research Themes

Advances in Modeling Dynamic Systems

Traditionally, IIASA has been strong in dynamic systems, control theory, stochastic optimization, decision theory, and game theory. The challenge is to develop novel approaches to these now standard models and tools, either via conceptual breakthroughs or by creatively combining and implementing multiple approaches. Possible breakthroughs can be achieved in the area of decision-making within the context of dynamic games with heterogeneous agents,
evolutionary and adaptive models, and robust solutions. Opportunities also exist for major advances by combining the analysis of dynamic systems with risk analysis and game theory to develop workable solutions to complex problems such as the current financial crisis or catastrophic failures in infrastructure networks.

In this context, comparative studies of alternative models addressing the same problem domain will be conducted. For example, it should be possible to compare a control-theory-based model with an agent-based (simulation) model in the domain of managing network risks in electrical grids. Through these comparisons, the advantages and disadvantages of alternative modeling approaches can be identified and, in particular, the scope of simplified models of intermediate complexity can be delineated. This type of comparison has been carried out in the energy and economics field for many years and IIASA is well positioned to organize such comparative studies by inviting modeler participation from institutions from NMO countries and around the world.

Extreme Events, Systemic Risks and Robust Solutions

Many standard techniques of systems analysis are based on optimization algorithms. IIASA has significant research experience in these modeling techniques including control theory, multiple objective analysis, and stochastic programming. In a world in which policymakers often face deep uncertainties (“unknown unknowns”) and highly complex dynamic and interlinked decision environments, traditional optimization techniques have limited usefulness. When facing extreme risks and highly unstable dynamic environments, alternative methods are needed. Models of robust decisions and of adaptive or resilient behavior should be explored. Game theory, experimental games, and behavioral decision research provide promising avenues for developing new approaches in this area.

A particular aspect of this research concerns systemic risk created by cascading failure in networks. Such risks arise in a broad variety of seemingly disparate systems, including interconnected financial markets, electrical grids, food-supply chains, disease dynamics, and transportation and communication networks. We propose to develop a framework for the analysis of systemic risk in complex dynamic networks and demonstrate its applicability to the management of networks. Theoretical exploration will employ deterministic, probabilistic and stochastic models of network dynamics, as well as Bayesian and non-Bayesian models of uncertainties. Analysis of changes in the states of a network’s nodes and in the network’s structure will be used to measure risk of non-desirable cascades, or collapses, in the network dynamics, to suggest a robust combination of anticipatory and adaptive risk management strategies, to carry out collapse prognosis and enhance preparedness, and to control a network’s repair from collapse, as well as resilient responses to a collapse. It is expected that studies of extreme events will use mathematical tools to explore common features of different types of extreme events. This would include clustering extreme events around those events with similar characteristics, e.g., the degree to which initiating events are known or knowable, the uncertainty about the consequences, and the complexity of the system itself that propagates a shock from initiating events to consequences.

Integrated Modeling and Decision Support

One of IIASA’s strategic objectives is to become more policy-relevant. To do so, it is important to ensure that IIASA’s databases and models are useable, used, and judged useful by researchers and policymakers around the world. There are numerous databases and models that are “housed” at IIASA. However, these models and databases usually reside in individual research programs, are maintained using specific formats and tools, and not all of them are easily accessible or, if accessible, may not be documented sufficiently to be used by other researchers. An important practical task of the ASA Program is to provide a modeling environment that
supports warehousing of data, models and results, with appropriate methods for access and service throughout the Institute and among collaborating researchers.

Another important task is to facilitate the use of models from different domains in an integrated assessment. IIASA’s energy models, its air pollution and greenhouse gas emission models, and food and agriculture models can and should be used in integrated assessments of policy options, for example, with respect to biofuel or nuclear energy use. This is challenging, as models have not only different domains but also different spatial and temporal extents and resolutions. An important activity in the future will be to facilitate the use of multiple models in integrated assessments. This will be carried out in the context of specific problem areas related to energy and climate change, food and water, and poverty and equity.

A related task is data harmonization, which includes data verification and smoothing as well as the scaling of model parameters and outputs to adjust for heterogeneity. The most important need is to enable a scaling from global or otherwise aggregated regional models to national models, as most policies are debated, tested and realized in a national context. Downscaling to the sub-national level, including levels at the county or city is even more challenging. These are mostly practical issues that will be primarily addressed in the context of specific research questions posed in IIASA’s three strategic problem areas.

**Advanced Systems Analysis Forum**

The Advanced Systems Analysis domain will contain a forum designed to promote interactions between in-house and external researchers. The Advanced Systems Analysis Forum will include IIASA’s methodological researchers and selected external researchers to present promising new methodologies and to discuss novel model-based and analytical approaches to addressing IIASA’s applied problems.

During the internal deliberations on planning for the research in advanced systems analysis, and also during the external workshops, it became clear that there is a need for innovation in systems analysis as we know it. The following ideas for innovations will be explored as part of the Advanced Systems Analysis Forum:

- The implications of game theory, experimental games and behavioral economics for the systems analysis work conducted at IIASA;
- The role of collective dynamics in creating surprises, innovation, discontinuities, phase transitions, regime shifts and tipping points in complex adaptive systems; and
- Unintended consequences of policies, extreme events and ripple effects
- Additional topics for the Advanced Systems Analysis Forum discussions include:
  - Developing an inventory of ASA expertise represented at IIASA;
  - Invigorating IIASA’s ASA portfolio with new methodological approaches not yet in use at IIASA, including
    - Dynamic games and other models of socioeconomic behavior
    - Models and analysis of adaptive behavior
    - Learning systems in and about uncertain systems
    - Models of risk and extreme events
    - Treatment of uncertainties evolving over long time horizons
    - Discounting in long-term dynamic systems
    - Closer integration of dynamic system models with GIS approaches
- Shared databases for collaborative research
- Development of a SimCity-like artificial world (the term used in internal discussions is “Dream Valley”) as a test bed for the simulation of interactions between economic, social, and environmental actors in the context of IIASA’s three strategic problem areas;
- Stimulating in-house exchanges about innovative ASA approaches by inviting lecturers, visitors and short-term ASA experts from around the world;
- In-house and Web-enabled teaching and education about advanced systems analysis methodologies and tools; and
- Participation in IIASA’s other capacity building activities.

The Advanced Systems Analysis Forum will initiate short-term exploratory projects. Some of these projects will be methodological; others will have the nature of “demonstration projects” that are meant to illustrate for the IIASA community and others how new methodologies can be used effectively in applied systems analysis.

**IIASA’s Strengths**

In recent years, IIASA’s methodological research was the main focus of two groups: the Dynamic Systems Program and the Integrated Modeling Environment Project. The Dynamic Systems Program has significant strengths in several modeling areas, notably dynamic systems and control theory. In recent years, other more applied capabilities were added with a focus on vulnerable infrastructure systems and extreme events. The strengths of the Integrated Modeling Environment Project have been in Web-enabled structured modeling, multi-criteria decision analysis, robust decision making under uncertainty and stochastic optimization. Recently added capabilities include integrated management of catastrophic risks, probabilistic downscaling, and providing systems analysis support for collaborating IIASA programs, including Web-based models and collaboration tools.

IIASA has also developed methodological strengths in its applied programs. For example, the Evolution and Ecology Program has expertise in game theory, adaptive dynamics theory, spatial dynamics, and in modeling the ecological and evolutionary dynamics of living systems. The Transition to New Technology (TNT) Program has developed agent-based modeling approaches to the study of evolving technologies. A number of programs address uncertainties, risks and robust solutions in modeling, and analysis of complex systems. The Risk, Policy and Vulnerability (RPV) Program has expertise in the stochastic analysis of extreme events, including extreme event distributions, simulation and optimization methods, and development of decision support tools. The Advanced Systems Analysis Program will serve as a resource to facilitate, coordinate, and cross-fertilize methodological research at IIASA while also exploring innovative methodological approaches that offer potential for applications.

IIASA is one of many modeling, simulation and analysis centers around the world, many of which are associated with university departments. Examples include the RAND Corporation, which pioneered some of the work in systems analysis and is among the leaders in robust modeling and decision-making and the Steklov Mathematical Institute at the Russian Academy of Sciences, which is a leader in the field of control theory. Both have much longstanding collaboration with IIASA. The Santa Fe Institute has pioneered much of the work in complex dynamic systems, and its researchers too have collaborated with IIASA on a number of related topics including dynamics of energy technologies. IIASA can reinforce its niche among these institutions by developing research activities that emphasize its strength in integrated modeling and assessment, combination of models of dynamic systems with game theoretic, multi-criteria and risk models, and a clear focus on a few applied problem areas.
Policy and Governance

Introduction

IIASA’s strategic plan declares that its research shall be problem-driven and solution-oriented, and provide knowledge and insight that can help policymakers and stakeholders respond to demanding global challenges. To accomplish this goal, IIASA must work with the policy community and stakeholder representatives throughout the research process: defining the research agenda and specific research questions; refining models as results come in and issues evolve; and communicating findings in clear and useful formats. Through these activities, IIASA will establish a feedback mechanism to ensure that the key points of the analyses have been accurately understood by decision makers so that they can be appropriately weighed in the relevant policy processes. These strategies must combine IIASA’s commitment to scientific integrity and autonomy with its ambition to help policymakers and stakeholders make good use of the best knowledge and insights that science can offer.

Governance is a critical component of a society’s capacity to respond effectively to major challenges. Governance mechanisms like the institutional arrangements for decision making and policy implementation, and regulations and economic incentives need to be considered as integral parts of IIASA’s systems analysis.

To increase IIASA’s policy relevance and to incorporate governance as a topic in systems analysis, this research plan includes the creation of a Policy and Governance Forum (PGF). This Forum will be an in-house support activity that works closely with IIASA research program and areas.

The first purpose of the PGF is to link IIASA’s research groups and activities more closely with the policy community by establishing a dialog in all phases of IIASA’s research, starting with the definition and scoping of the problem to be studied. Not all researchers are knowledgeable about the world of policymakers, and few policymakers understand the research world. Both communities have different time frames—years in the case of researchers, weeks (and sometimes days) in the case of policymakers. Researchers feel comfortable with mathematics, data, and models; policymakers often want answers and clear-cut guidance rather than complicated analyses. To bridge this divide is a great challenge, which will involve gradual relationship building, joint policy-research projects, and efforts to demonstrate IIASA’s value-added to the policy community.

The second purpose is to infuse the notion of governance into IIASA research. Governance concerns institutional arrangements, regulatory and other policy instruments, as well as the involvement of stakeholders, including government, industry and non-governmental institutions. To help IIASA researchers better bridge the science-policy gap, it will be necessary to develop a clearer understanding of the local, regional, national and global policy arenas in which IIASA’s research can contribute. With this understanding the PGF will encourage IIASA’s researchers to look beyond straightforward policy options like regulation and taxation and consider broader institutional and governmental processes as elements for addressing the problem areas in which the programs are engaged.
Research Themes

The Policy and Governance Forum will be an in-house support activity that works closely with IIASA researchers and builds links to the policy community on international, national, and local levels as appropriate. The Forum will bring together IIASA researchers engaged in policy-relevant research, external participants who have shown exceptional skills in conducting real-world policy, decision or negotiation analyses, and policymakers with an interest in using models and analysis to improve decision making. International negotiations will also be an important element of this activity.

International development cooperation was identified as a particular policy and governance context in which IIASA will expand its contribution, in light of the Institute’s growing membership among developing countries. The PGF will therefore explore how IIASA’s research can be used to support supranational (e.g., DG EuropeAid at the European Commission), multilateral funding agencies (e.g., World Bank, UNDP) and bilateral funding agencies (e.g., USAID, SIDA, and others in IIASA member countries) in designing and evaluating their strategies and programs. Work with ministries responsible for coordination of international development cooperation in IIASA’s new member countries may also be possible, particularly in connection with the Poverty and Equity Area.

Other purposes of the Policy and Governance Forum include the following:

- Further development of links between research activities and the policy community through policy briefs and by offering responses to policy questions in the area of IIASA research.
- Conduct policy, decision and negotiation analysis on specific problems posed by NMOs, in close cooperation with policymakers and IIASA researchers and external partners.
- Collaborate with IIASA’s advance systems analysis researchers and policymakers to develop new user-friendly Web-based tools to support policy decisions.
- Investigate how governance options can be incorporated into IIASA’s modeling and analysis activities.

The PGF will explore ideas in consultation with researchers and external experts. The following offer projects and directions for which IIASA might pursue external funding to augment ongoing activities at IIASA:

- Manual of best practices on bridging scientific research and policymaking at IIASA, including many existing practices at IIASA that need to be systematically catalogued, analyzed, and presented so as to provide guidance and good practices for IIASA as a whole.
- Demonstration/pilot projects that consist of activities at IIASA designed to show “bridging science and policy” in action on specific subjects of global interest (climate change negotiations regime/climate change governance, policy analysis in specific topical areas such as biofuels).
- Development of policy analysis tools that are based on simplified versions of IIASA’s models and analysis capabilities, yet capture the essence of their insights. These tools should be user-friendly, dynamically updated in real time, and provide a “feel” for the relationships between parameters that the policymakers can control. The outputs of the analysis should be highly visual and facilitate user exploration instead of model optimization. They should provide insights in the process of making tradeoffs.
• Occasional speakers series of series of lectures by world-recognized experts on the science–policy interface and policy analysts and will be organized to cover a wide varieties of subjects of interest to the research programs at IIASA

• Sabbatical/visitors program for officials who work actively on the science–policy interface, for example, science advisors of major government agencies in IIASA member countries.

• Policy and governance dialogs that bring experts and policymakers together in a roundtable forum designed to frame policy problems, develop policy and governance objectives and options, identify conflicts, identify research and analysis needs and, if applicable, design and implement stakeholder involvement and conflict resolution processes.

IIASA’s Strengths

IIASA has made contributions to policy development in two main ways. First, IIASA has conducted assessments that were useful in several policy contexts. Examples are IIASA’s role in the acid rain debate in Europe, the economic reform in Russia, and in the IPCC’s assessments of climate change scenarios, mitigation, impacts and adaptation. Less successful have been to turn these experiences into institutional and systematic practices that bridge the gap between science and policymaking. One of the objectives of the Policy and Governance Forum will be to introduce activities at IIASA to address the policy interface more systematically. Second, IIASA has identified many of the attributes of governance that facilitate or hinder a systems-oriented approach to problem solving. Examples are the Sustainable Development of the Biosphere Project, which identified key features of adaptive management and research on risk governance supported by model-based stakeholder processes. A second objective of the Policy and Governance Forum will be to reflect on and draw lessons from these and related experiences with the use of systems analysis in the policy process.

While IIASA has experience in developing connections to the policy world (for example, advisory boards, consultations with the UN Secretary-General, negotiation support), it has not studied policy and governance as a research topic per se, and it has no ambition of competing with the pre-eminent institutions in the world in this area. By incorporating governance into its systems analysis, IIASA can, however, bring its strength in quantitative modeling and simulation to bear also on the analysis of policies and institutions and thereby enhance understanding of governance as an integral component of the capacity to cope with major challenges. Moreover, the Institute offers neutral ground for analyzing contentious and sensitive transboundary governance issues such as water supply and quality, atmospheric pollution (including greenhouse gases), or regional approaches to the ramifications of large-scale climate change such as those occurring in the Arctic.

The PGF will collect examples from IIASA’s policy experiences and catalog them to serve as guidance and support to research programs. Two examples of programs that have made a determined effort to bridge science and policy are presented briefly below: the Global Energy Assessment (GEA) and the Greenhouse Gas and Air Pollution Synergies (GAINS) model.

The Global Energy Assessment. One of the main goals of the Global Energy Assessment is that it should become a reference tool for energy policy and decision making. As a result, an inherent feature of its design is the constant effort to ensure that GEA bridges science and research with policy relevance and tools for decision making. These features are built into the following: the process used in the research and preparation of each knowledge module, the process of consultation through policy dialogs and stakeholder meetings throughout the process, the design and structure of the manuscript, and the focus on the design of policy tools.
Outreach, stakeholder consultations, and policy dialogs with decision-makers (the latter to be intensified in 2010 throughout all the regions of the world) are central to the relevance and success of the Assessment. These are opportunities not only for getting feedback on the work but also for making sure that the GEA is on track and dealing with “state-of-the-art” knowledge on energy. These early consultations will also pave the way for future dissemination. The goal is, as much as possible, to incorporate the insights from these interactions and suggestions into the design of the GEA.

**GAINS Model.** IIASA’s GAINS model aims to support policy analyses and decisions by providing a comprehensive systems perspective on the complexities of controlling atmospheric pollution without placing an unnecessary burden on economic development. In the past GAINS and its predecessor, the RAINS model, have been used to inform numerous negotiations on European air pollution accords under the UNECE Convention on Long-range Transboundary Air Pollution and the European Union, where the tool provides a common knowledge base that brings together quality-controlled information from all participating countries. The recent extension to GAINS allows the comparison of countries’ mitigation efforts that are implied by the negotiation pledges to the UNFCCC.

It is important that GAINS and RAINS are developed and applied in a participatory process involving potential users and stakeholders. This allows the focus of the analysis to be tailored to policy-relevant questions, and the policy discussions to be framed to increase the effectiveness of potential policy agreements. Credibility, salience and legitimacy are the key characteristics contributing to the successful policy applications of these IIASA models.

**Summary**

Table 2 shows a summary of this section in terms of areas, themes, and how IIASA’s research programs can contribute to them.

<table>
<thead>
<tr>
<th>Crosscutting Areas</th>
<th>Crosscutting Research Themes</th>
<th>Participating Programs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Drivers of Global Transformations</strong></td>
<td>Understanding population-level diffusion of new technologies and acceleration technological diffusion</td>
<td>TNT (technology diffusion) POP (age structure and technological adoption) RPV (policy)</td>
</tr>
<tr>
<td></td>
<td>Interaction between population, education, poverty and equity</td>
<td>POP (demographics, economic growth) RPV (vulnerabilities, policy)</td>
</tr>
<tr>
<td></td>
<td>Urbanization and migration</td>
<td>POP (demographic changes) ASA (mathematical models of migration) RPV (policy)</td>
</tr>
<tr>
<td></td>
<td>Sustainable economic growth</td>
<td>ASA (mathematical modeling of economic growth) POP (demographics of growth) RPV (vulnerabilities, risks)</td>
</tr>
<tr>
<td><strong>Advanced Systems Analysis</strong></td>
<td>Advanced dynamic modeling</td>
<td>ASA (dynamic modeling) EEP (evolutionary games, advanced methods)</td>
</tr>
<tr>
<td>Crosscutting Areas</td>
<td>Crosscutting Research Themes</td>
<td>Participating Programs</td>
</tr>
<tr>
<td>-------------------</td>
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</tr>
</tbody>
</table>
| Extreme events, systemic risks, and robust solutions | ASA (systemic risks, uncertainty)  
RPV (risk, extreme events)  
EEP (network dynamics) | |
| Integrated modeling and decision support | ASA (integrated modeling, models and data warehousing, decision support)  
Other programs (linkages to program specific models and data bases) | |
| Advanced Systems Analysis Forum | All IIASA researchers with an interest in methodology participate in this forum with invited experts providing special new expertise | |
| **Policy and Governance** | Policy and Governance Forum | All Programs participate in this round table forum together with policymakers and policy analysts from NMO organizations |
Part C

Program Descriptions
Energy Program

Program Focus and Relevance

The objective of the Energy (ENE) Program is to provide scientific and strategic analysis to further understanding of the dynamics of future energy transformations, their main driving forces, enabling factors and barriers, and their consequences for the social, economic and environmental dimensions of human wellbeing. The ENE research topics are thus at the core of a number of the central research areas at IIASA, including the energy dimension of the Poverty and Equity Area and the implications of energy supply in the Food and Water Area.

The program’s focus is to improve scientific understanding of viable policy mechanisms that would permit the transformation of the present energy system to a cleaner and more sustainable one. This includes the application and development of formal modeling tools for the integrated assessment of major energy-related environmental, social and economic challenges. The strategic goal is to guide decision making in the design of integrated solutions to address climate change, energy access, pollution, energy security and other local development goals simultaneously. Focus is given to the exploration of synergies and potential tradeoffs between the diverse policy priorities and ways of transforming the system to maximize multiple benefits across them.

The ENE research plan will be implemented in close collaboration with IIASA Programs on Mitigation of Air Pollution and Greenhouse Gases (MAG), Advanced Systems Analysis (ASA) Ecosystems Services and Management (ESM), and Transition to New Technologies (TNT). The primary focus of ENE collaborative activities will be within the Energy and Climate Area: with TNT on drivers of change and with MAG on indoor air pollution and synergies between air pollution and climate change. However, links are also foreseen within the Food and Water Area with ESM to explore the critical issue of competition for land between bioenergy, food and fiber; with the Poverty and Equity Area to examine issues of energy access; and with ASA to apply multi-criteria methods for the integrated assessment of policy tradeoffs and synergies.

In addition to the existing scientific and policy networks, spin-offs of ENE’s Global Energy Assessmen (GEA)t will provide a platform for the new IIASA research activities in the Energy and Climate Area.

Building on Current Program Expertise and Past Achievements

ENE builds upon a long tradition of energy-related research at IIASA going back to the foundation of the Institute and thus has ample experience in the economic, technology and climate dimensions of global and regional energy issues. Major achievements involving ENE staff have included an inventory of more than 1,500 energy and emissions mitigation technologies (CO2DB), studies on the dynamics of energy technologies, contributions to all four assessment reports of the Intergovernmental Panel on Climate Change (IPCC) and in particular to the Special Report on Emissions Scenarios, to the World Energy Assessment, and publication of a number of policy oriented energy scenarios including the joint book with the World Energy Council (WEC) on Global Energy Perspectives published in 1998.
In 2006 the new ENE Program was launched emphasizing holistic modeling approaches and integrated assessment, and this has fostered various external and also in-house collaborative activities with a number of IIASA Programs, including TNT, ESM and MAG. Important external collaborative activities in addition to the Global Energy Assessment (GEA) comprise in particular the creation of the Integrated Assessment Modeling Consortium (IAMC), co-led by ENE, which put the program at the forefront of the coordination activities of the climate research community for the new integrated scenarios for the IPCC’s Fifth Assessment Report.

To understand the complex dynamics of the energy system and its interaction with other main economic sectors, ENE has, in recent years, used different modeling and scenario approaches, including those based on endogenous technological change, integration of energy-economy-environment interactions, energy end use and services, uncertainty and heterogeneity. Particularly in the field of climate change, ENE has extended collaborative research within IIASA to develop and maintain the IIASA Integrated Assessment Framework. Substantial efforts were also made between 2007 and 2009 toward developing spatially explicit emissions and land-cover-change projections of the so-called Representative Concentration Pathways (RCPs), which will form the analytical backbone of the climate change projections of the IPCC’s Fifth Assessment Report. In addition to providing one of the RCP projections, ENE is hosting the IPCC-RCP scenarios database (http://www.iiasa.ac.at/web-apps/tnt/RcpDb), through which the Integrated Assessment community is organizing its data dissemination.

Between 2006 and 2009 ENE enhanced and extended its integrated assessment tools (e.g., MESSAGE) and developed novel operational methodologies going beyond the traditionally often simplified (deterministic) representation of energy, economic and environmental interactions to endogenous representation of salient energy uncertainties and their implication for decision making. Emphasis was also given to an explicit representation of rural and urban energy use and behavioral heterogeneity for the analysis of policies to promote universal access to clean and affordable energy services (case study on India).

The Global Energy Assessment was established by IIASA and its partner organizations to help decision makers address the challenges of providing energy services for sustainable development. The GEA aims to redefine the energy policy agenda and addresses major contemporary energy challenges in an integrated and comprehensive fashion. Presently, approximately 275 analysts and 200 reviewers are working on the GEA, with truly global representation of a variety of expertise.

The ENE research activities in the next research program cycle will include both scenario analysis based on large-scale integrated assessment modeling and exploratory research projects with a strong methodological focus.

Integrated assessment work will be geared toward the identification of linked solutions in order to simultaneously address major energy-related challenges of climate change, energy security, energy poverty, and pollution. Particular emphasis will be given to tradeoffs and synergies between the various energy objectives to identify regional and global “win–win” strategies.

Methodology development will focus on (i) behavioral changes, lifestyles and consumption patterns as critical drivers of future energy demand; (ii) social heterogeneity for a better understanding of policy instruments that would help to connect the poorest to affordable and modern energy; and (iii) spatial heterogeneity to explore the dynamics of technology development and diffusion, their constraints and policies to overcome them.

**Five Representative Recent Research Publications**


**Five Representative Recent Policy Applications**


**Human Resources (excluding guest scholars)**

*Full Time*

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Field of expertise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keywan Riahi</td>
<td>Acting Program Leader/ Senior Research Scholar</td>
<td>Energy economics, climate change</td>
</tr>
<tr>
<td>Yuji Kobayashi</td>
<td>Research Scholar</td>
<td>Technology trade and transfer</td>
</tr>
<tr>
<td>Volker Krey</td>
<td>Research Scholar</td>
<td>Energy systems analysis, stochastic modeling</td>
</tr>
<tr>
<td>Shonali Pachauri</td>
<td>Senior Research Scholar</td>
<td>Energy poverty and access</td>
</tr>
<tr>
<td>Oscar van Vliet</td>
<td>Research Scholar</td>
<td>Mobility and energy system modeling</td>
</tr>
<tr>
<td>Name</td>
<td>Position</td>
<td>Field of expertise</td>
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<tr>
<td>-------------------------</td>
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</tr>
<tr>
<td>Ged Davis</td>
<td>GEA Council Co-President</td>
<td>Energy and environment, Energy scenarios</td>
</tr>
<tr>
<td>Jose Goldemberg</td>
<td>GEA Council Co-President</td>
<td>Renewable energy, Sustainable development and policies</td>
</tr>
<tr>
<td>Luis Gomez-Echeverri</td>
<td>Executive Coordinator</td>
<td>Global energy assessment</td>
</tr>
<tr>
<td>Thomas Johanson</td>
<td>GEA Co-Chair</td>
<td>Environmental economics, climate studies, energy</td>
</tr>
<tr>
<td>Peter Kolp</td>
<td>Research Associate</td>
<td>Software engineering, modeling</td>
</tr>
<tr>
<td>Nebojsa Nakicenovic</td>
<td>Deputy Director / Senior Research Scholar</td>
<td>Energy, technology, integrated assessment</td>
</tr>
<tr>
<td>Yu Nagai</td>
<td>Research Assistant</td>
<td>Energy access modeling</td>
</tr>
<tr>
<td>Anand Patwardhan</td>
<td>GEA Co-Chair</td>
<td>Environment climate studies, Assessment of vulnerability and adaptation to climate change</td>
</tr>
<tr>
<td>Shilpa Rao</td>
<td>Research Assistant</td>
<td>Pollution and climate change</td>
</tr>
<tr>
<td>Manfred Strubegger</td>
<td>Senior Research Scholar</td>
<td>Energy system modeling</td>
</tr>
<tr>
<td>Diana Urge-Vorsatz</td>
<td>Senior Research Scholar</td>
<td>Energy efficiency and end use focus on buildings</td>
</tr>
<tr>
<td>Bing Zhu</td>
<td>Research Scholar</td>
<td>Climate mitigation, Asia</td>
</tr>
</tbody>
</table>

Representative Recent Collaborating Institutions

Central European University (Hungary), Electric Power Research Institute (EPRI, USA), Energy Research Institute (China), Elettra Solar (Germany), German Advisory Council on Global Change (WGBU, Germany), German Aerospace Center (DLR, Germany), Indian Institute of Management (IIAM, India), Institute of Technology Bombay (IIT, India), Intergovernmental Panel on Climate Change (IPCC), International Atomic Energy Agency (IAEA), International Council for Science (ICSU), International Renewable Energy Agency (IRENA), Joint Research Centre (JRC, European Commission), Kwame Nkrumah University of Science and Technology (KNUST, Ghana), National Center for Atmospheric Research (NCAR, USA), National Institute of Environmental Studies (NIES, Japan), National Laboratory for Sustainable Energy (RISO, Denmark), National Renewable Energy Laboratory (NREL, USA), IRADE (India), Netherlands Environmental Assessment Agency (PBL, Netherlands), OMV (Austria), Pacific Northwest National Laboratories (PNNL, USA), PetroBras (Brazil), Potsdam Institute for Climate Impact Research (PIK), Princeton University (USA), RAND Corporation (USA), Renewable Energy Policy Network for the 21st Century (REN21), Research Institute of Innovative Technology for the Earth (RITE, Japan), Santa Fe Institute (USA), Stanford University (USA), Technical Research Centre of Finland (VTT, Finland), The Energy and Resources Institute (India), Tokyo Electric Power Company (TEPCO, Japan), Tsinghua University (China), United Nations Environment Programme (UNEP), United Nations Framework Convention on Climate Change (UNFCCC), United Nations Industrial Development Organization (UNIDO), United Nations United Nations Department of Economic and Social Affairs (UNDESA), University of California (USA), University of Cape Town (South Africa), University of Lund (Sweden), University of Michigan (USA), University of Oxford (UK), University of Tokyo (Japan), Virginia Tech (USA), World Bank (USA), World Business Council for Sustainable Development (WBCSD), World Health Organization (WHO), World Resources Institute (WRI, USA), World Wildlife Fund (WWF, USA), World Food Programme (WFP, USA).
The ENE Program also hosts the Global Energy Assessment (GEA) at IIASA that includes a collaborative network of over 275 analysts from more than 180 institutions encompassing academia, industry, non-governmental and international organizations. Analysts in the GEA network represent over 40 nations spanning all regions of the globe, including strong membership from outside the OECD. An additional 200 experts are serving as external reviewers.

External Contracts and Grants Extending into 2011 And Beyond

ENE’s external funding totaled Euro 1,286,480 in 2009 and 1,084,784 in 2010. Most of these funds support the Global Energy Assessment. Sponsoring organizations include inter alia government agencies from Austria, the European Commission, Germany, Italy, Norway, Sweden and the USA. Other sponsors include: The Global Environmental Facility, United Nations Department of Economic and Social Affairs, United Nations Development Programme, United Nations Environment Programme, United Nations Industrial Development Organization, World Bank (ESMAP). The Climate Works Foundation, First Solar Inc., Global Environment and Technology Foundation, Petrobras, Brazil, United Nations Foundation, USA, World business Council for Sustainable Development and the World Energy Council.

Three additional externally funded contracts extend into 2011. All three projects are closely related to the central objective of the Energy and Climate Area of the IIASA Strategic Plan for 2011–2020 namely, to enhance understanding of the dynamics of future energy transformations, their main driving forces, enabling factors and barriers, and their consequences for the social, economic and environmental dimensions of human wellbeing. The focus of the projects are on: (i) improving representation of spatial characteristics of critical technologies (such as renewables) in Integrated Assessment models (European Commission, EnerGEO Project); (ii) improving the understanding of the role of technology transfer in climate mitigation (TEPCO, Japan); and (iii) exploring attainability, costs and multiple benefits of the transition toward a sustainable future energy systems with deep cuts in greenhouse gas emissions and high levels of energy security (RITE, Japan). Two of the three projects include collaboration with other programs at IIASA to enhance crosscutting integrative work across ENE, namely, ESM, and MAG.

In addition to ENE contracts, one external grant for the Global Energy Assessment (GEA) aims to implement the second phase of GEA to make the results of its initial phase more policy-friendly and to enhance the implementation and uptake of its findings. Through regional and sub-regional assessments, GEA II will seek to address the place-specific challenges facing different countries and regions, organized into different subsets on the basis of a comprehensive set of indicators of energy sustainability, e.g., risk, resilience, capacity, intensity and concentration, among others. Current and emerging energy challenges and opportunities most relevant to each regional and typological group will be examined and reported through specific case studies and the application of place-specific analytical approaches. These will be complemented by country studies that are broadly inclusive of the energy challenges being faced by decision makers at the national level. GEA II will also research specific themes and produce more focused studies and written briefs on high-profile issues, challenges and opportunities for targeted near-term action. In addition, a regional and country-level dialog will be undertaken to move toward consensus on adoption of policies and market instruments that enable sustainable energy systems. This will lead to the preparation of policy tools and options tailored to decision makers. Related to the policy dialogs, GEA II will partner with national
institutions and national leaders in the development and use of policy tools that will aim to improve the capacity for effective decision making.

The ENE Program has a number of ongoing activities and proposals in the pipeline expected to materialize in the course of the early 2011. These include (i) strategic collaboration with the main international climate research communities and the IPCC, where ENE will take a leading role in the coordination of certain research activities; (ii) regional collaborations with key researchers in IIASA NMO countries, for example, the Asian Modeling Exercise (AME), the Energy Modeling Forum (EMF), and the European Commission project AMPERE which aims to build the backbone of joint European research on the integrated assessment of climate change. In addition, collaborative activities with technology and energy resource experts, such as, the National Renewable Energy Laboratory (NREL), USA, form important complements to networking activities.
Mitigation of Air Pollution and Greenhouse Gases Program

Program Focus and Relevance

The objective of the Mitigation of Air Pollution and Greenhouse Gases (MAG) Program is to develop and apply systems analytical tools to inform national and international policy decisions on cost-effective emission reductions to protect human health, the local and regional environment and global climate. In addition, by addressing the nitrogen cycle and the health impacts of indoor air pollution, it links closely with the Food and Water and Poverty and Equity Areas.

Given the need for a fundamental restructuring of long-lived infrastructure, transition strategies that achieve deep cuts in greenhouse gas emissions by midcentury must be initiated in the near term at the national and local scales. Yet, there is only sparse understanding of: (i) what such low carbon societies would look like; (ii) how the fundamental changes required for transition could be effected by current institutions; and (iii) what policy decisions need to be taken in the near future at the national and local level so as not to compromise the attainability of overall mitigation targets.

In the new research planning period the MAG Program will develop practical tools that inform national planners in industrialized and developing countries about transition strategies to low-carbon economies. The program will use a systems perspective to include all relevant economic sectors and their interactions to highlight how policy objectives such as economic development, energy and food security, local air quality, human health, and adaptation to climate change can be achieved with positive co-benefits to climate change.

Through this analysis the program will make key contributions to the Energy and Climate Area by complementing the global-scale investigations of the Energy (ENE) Program with assessments that are of immediate relevance to national decision makers. The systems perspective developed by MAG on the nitrogen cycle will contribute to activities of the Food and Water Area, and its assessment of health effects in terms of indoor pollution from biomass combustion will also be part of the work planned in the Poverty and Equity Area.

Building on Current Program Expertise and Past Achievements

In the past, MAG has successfully developed integrated assessment tools for the analysis of cost-effective strategies to reduce impacts of air pollution and the reduction of greenhouse gas emissions up to 2030. Its GAINS model has been implemented for Europe, China and India as well as for the Annex I countries of the UNFCCC to quantify national potentials for mitigating air pollution and greenhouse gas emissions, their costs and their environmental benefits. The GAINS model has been used for a wide range of policy analyses for international negotiations on emission reductions under the UNEC on Long-range Trans-boundary Air Pollution, the European Union and the UNFCCC. GAINS provides a systems perspective that quantifies interactions between measures for different economic sectors, different pollutants, different
environmental effects occurring at different spatial and temporal scales, and in different countries. MAG has a long-standing record in involving stakeholders throughout the assessment process, from the design phase through validation of input data to the development of policy analyses.

The new work will build upon databases of the current GAINS model. This will allow MAG to involve scientific networks currently engaged in the GAINS-based analyses and to develop further perspectives for the international policy communities that are currently informed by the GAINS assessments. The model aims to respond to the needs of national decision makers in individual OECD and BRICS (Brazil, Russia, India, China, South Africa) countries that deal with resource planning, technology development and deployment, urban planning, land use, as well as restructuring existing tax and incentive schemes. It thus offers a natural connection to constituencies in IIASA NMO countries.

Five Representative Recent Research Publications


Five Representative Recent Policy Applications


Human Resources (excluding guest scholars)

**Full time**

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Field of expertise</th>
</tr>
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<tbody>
<tr>
<td>Markus Amann</td>
<td>Program Leader</td>
<td>Economics</td>
</tr>
<tr>
<td>Hans Benzinger</td>
<td>Administrative Coordinator</td>
<td>European studies</td>
</tr>
<tr>
<td>Imrich Bertok</td>
<td>Research Scholar</td>
<td>Computer Science</td>
</tr>
<tr>
<td>Jens Borken-Kleefeld</td>
<td>Research Scholar</td>
<td>Environmental Physics</td>
</tr>
<tr>
<td>Janusz Cofala</td>
<td>Senior Research Scholar</td>
<td>Energy Economics</td>
</tr>
<tr>
<td>Christopher Heyes</td>
<td>Senior Research Scholar</td>
<td>Chemistry</td>
</tr>
<tr>
<td>Zbigniew Klimont</td>
<td>Research Scholar</td>
<td>Environmental Engineering</td>
</tr>
<tr>
<td>Binh Nguyen</td>
<td>Research Scholar</td>
<td>Software Engineer</td>
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<tr>
<td>Pallav Purohit</td>
<td>Research Scholar</td>
<td>Energy policy and planning</td>
</tr>
<tr>
<td>Peter Rafaj</td>
<td>Research Scholar</td>
<td>Energy Economics</td>
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<tr>
<td>Robert Sander</td>
<td>Research Associate</td>
<td>Software Developer</td>
</tr>
<tr>
<td>Wolfgang Schöpp</td>
<td>Senior Research Scholar</td>
<td>Economics</td>
</tr>
<tr>
<td>Fabian Wagner</td>
<td>Senior Research Scholar</td>
<td>Theoretical Physics</td>
</tr>
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</table>

**Part Time**

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<thead>
<tr>
<th>Name</th>
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<th>Field of expertise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maria Gunther-Axelsson</td>
<td>Research Scholar</td>
<td>High-energy Physics</td>
</tr>
<tr>
<td>Geza Toth</td>
<td>Research Assistant</td>
<td>Natural Resources Management</td>
</tr>
<tr>
<td>Erich Striessnig</td>
<td>Research Assistant</td>
<td>Economics</td>
</tr>
<tr>
<td>Wilfried Winiwarter</td>
<td>Senior Research Scholar</td>
<td>Analytical Chemistry</td>
</tr>
<tr>
<td>Lena Höglund-Isaksson</td>
<td>Research Scholar</td>
<td>Economics</td>
</tr>
</tbody>
</table>

Representative Recent Collaborating Institutions

Collaborators in joint projects in IIASA NMO countries include the Joanneum Research Forschungsgesellschaft, Graz, Austria; European Topic Centre on Air and Climate Change, Umweltbundesamt Vienna, Austria; Technische Universität Wien, Austria; Department of Environmental Science and Engineering, Tsinghua University, Beijing, China; National Development and Reform Commission Energy Research Institute, Beijing, China; Peking University, Beijing, China; Cairo University, Center for Environmental Hazard Mitigation, Cairo, Egypt; Finnish Environment Institute, Helsinki, Finland; University of Helsinki, Department of Physical Sciences, Helsinki, Finland; University of Bonn, Institute for Food and Resources, Bonn, Germany; Deutsches Zentrum für Luft- und Raumfahrt (DLR), Germany;
External Contracts and Grants that Extend into 2011 And Beyond

The total external funds for MAG’s research was Euro 1,754,427 in 2009 and 1,932,298 in 2010.

MAG’s ambitious externally funded research program focuses on further development and application of the GAINS model system for climate and air pollution policy assessments. Activities include model improvements, linkage with energy, agricultural, transport and benefit assessment models, peer review of methodologies, update of input data, validation of input data with stakeholders from Member States and industry, as well as actual policy analyses for negotiations under the Convention on Long-range Trans-boundary Air Pollution and the European Union.

Research contracts have been established inter alia with the United Nations Economic Commission for Europe, Geneva, Switzerland; the United Nations Environment Programme, Nairobi, Kenya; the World Health Organization (WHO), Rome; the International Energy Agency, Paris, France; The Oil Companies European Organization for Environment, Health, and Safety (CONCAWE), Belgium; Toyota Motor Corporation, Japan; the European Climate Foundation, Brussels, Belgium.
The Ecosystems Services and Management (ESM) Program was formed through a merger of the previous Land Use and Land Use Change (LUC) and Forestry (FOR) Programs. The research program descriptions given are based on the two component programs.

**ESM–Forestry (FOR)**

**Program Focus and Relevance**

The world’s ecosystems face numerous and diverse challenges, threats and risks. Climate change may exceed the stability thresholds and buffering capacity of forest ecosystems in many of the world’s regions by the middle of this century. Forest and other ecosystem losses and degradation are well documented. Governance of forests in many countries is poor. However, the challenging problems facing the globe’s forests cannot be solved only from within the forest sector. Worsening shortages of land, water, food and energy, and growing conflicts in policies and strategies, demand a broader view if sustainable use is to be achieved.

The objective of the ESM–Forestry (FOR) Program is to contribute to the understanding of the future trajectories, vitality and services of terrestrial ecosystems at different scales and to develop advanced methodologies and tools for appropriate integrated policy responses. The FOR part of the ESM Program in this research period is related to the three global problem areas of IIASA’s Strategic Plan: (1) Food and Water; (2) Poverty and Equity; and (3) Energy and Climate Change, as well as to the Drivers of Global Transformations—population growth and technology development and diffusion.

ESM–FOR will direct its research, which will be centered around its existing Integrated Modeling Cluster—a tool designed for studying complex problems of integrated land and ecosystems management with emphasis on Earth Observations (EO), Sustainable Ecosystem Management (SEM), and Policy and Governance (PG). Close collaboration with the Policy and Governance Forum is expected.

**Building on Current Program Expertise and Past Achievements**

ESM–FOR has developed an initial version of an Integrated Modeling Cluster—a tool designed for studying complex problems of integrated land and ecosystems management with emphasis on
on forests and their sustainable management. The program has developed a research framework and a network, which includes not only other IIASA programs but also numerous institutions across Europe, Africa, Asia and the Americas. The results obtained by the program had substantial policy impacts. In a number of international and national activities the program has been a direct contributor to the policymaking process (e.g., REDD in Africa, GEO Science and Technology Committee, some ESA initiatives). Scientific findings of the program have been officially introduced into forest management practice by some countries (e.g., Russia), and have supported international negotiations and decision making (e.g., LULUCF sector at COP15).

Thus, the focus of ESM–FOR’s future research is to further develop the integrated view of all relevant terrestrial ecosystems and their services with emphasis on forests, by applying integrated models as management tools.

The program aims at the development, first, of a global view of a sustainable structure of natural landscapes and the role of major stabilizing components (forests, wetlands) in integrated land management under global change. Second, it intends to assess the impacts of global ecosystems, with special reference to climatic hotspots (e.g., permafrost areas) and critical land use changes (e.g., deforestation in the tropics), and the stability of the Earth system. Third, it plans to carry out an integrated assessment of sustainable land management, including land conflict between landscape stability and food and energy production. Finally, ESM–FOR will analyze ecological and socioeconomic harmonization of mitigation and adaptation measures within the sustainable land and ecosystem management paradigm.

To accomplish these goals, further methodological development will be needed. The focus will be on further developing the program’s methodological framework and instruments for practical applications of applied systems analysis via integrated modeling applied to an integrated land-use management system. This approach places FOR’s research interests above the forest sector and requires consideration of the entire landscape with all the diversity of its land cover including agriculture, forests, wetlands, populated areas etc., as well as interactions and conflicts with the socioeconomic sector (e.g., conflict of land for production of food and energy). A holistic approach to integrated modeling will be used to further develop and improve the ESM–FOR Integrated Modeling Cluster. Substantial efforts are planned principally to improve the information environment of integrated modeling through embedding the multisensor remote sensing concept in integrated land information systems and the development of a Global Forest Observatory. A planned monograph (2011–2013) Applied Systems Analysis and Integrated Modeling in Forestry and Land Management will contribute to capacity building in NMO countries and elsewhere. The major core projects suggested by ESM–FOR (Climate Change-Management and Policy, Climate Change Mitigation and Vulnerability, Role of Ecosystems in the Global Biogeochemical Cycles, Ecosystems Degradation and Water Provision and Ecosystems) contribute to the fundamental scientific goals of the Strategy Plan and are collaborative projects with several other IIASA Programs and the ESM–FOR research network.

Five Representative Recent Research Publications


**Five Representative Recent Policy Applications**


**Human Resources (excluding guest scholars)**

*Full Time*

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Field of expertise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anatoly Shvidenko</td>
<td>Acting Program Leader</td>
<td>Ecology, Forestry</td>
</tr>
<tr>
<td>Florian Kraxner</td>
<td>Acting Deputy Program Leader</td>
<td>Socioeconomics of the forest sector, bioenergy systems</td>
</tr>
<tr>
<td>Kentaro Aoki</td>
<td>Research Scholar</td>
<td>Forest Ecology, Forest Hydrology,</td>
</tr>
<tr>
<td>Hannes Böttcher</td>
<td>Research Scholar</td>
<td>Forest, Land-use Change and Bioenergy</td>
</tr>
<tr>
<td>Steffen Fritz</td>
<td>Research Scholar</td>
<td>Geography, remote sensing</td>
</tr>
<tr>
<td>(Karl) Oskar Franklin</td>
<td>Research Scholar</td>
<td>Ecology, Forestry</td>
</tr>
<tr>
<td>Sabine Fuss</td>
<td>Research Scholar</td>
<td>Economics, stochastic optimization</td>
</tr>
<tr>
<td>(Sarah) Marianne Hall</td>
<td>Post-Doc</td>
<td>Forest ecology</td>
</tr>
<tr>
<td>Name</td>
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<tr>
<td>Petr Havlik</td>
<td>Research Scholar</td>
<td>Agricultural Economics</td>
</tr>
<tr>
<td>Matthias Jonas</td>
<td>Research Scholar</td>
<td>Geophysics</td>
</tr>
<tr>
<td>Nikolay Khabarov</td>
<td>Research Scholar</td>
<td>Control theory and optimization</td>
</tr>
<tr>
<td>Sylvain Leduc</td>
<td>Research Scholar</td>
<td>Bio-Energy Engineering</td>
</tr>
<tr>
<td>Myroslava Lesiv</td>
<td>PhD Student</td>
<td>Mathematical Modeling</td>
</tr>
<tr>
<td>(Nils) Ola Lindroos</td>
<td>Post-Doc</td>
<td>Socioeconomics</td>
</tr>
<tr>
<td>Anders Lunnan</td>
<td>Professor (at IIASA on sabbatical from home university)</td>
<td>Forest Policy and Economics</td>
</tr>
<tr>
<td>Aline Mosnier</td>
<td>Research Scholar</td>
<td>Development Economics and Trade</td>
</tr>
<tr>
<td>Michael Obersteiner</td>
<td>Senior Research Scholar</td>
<td>Ecosystem Management, Natural Resource Economics</td>
</tr>
<tr>
<td>Dmitry Schepaschenko</td>
<td>Research Scholar</td>
<td>Ecology, Forestry</td>
</tr>
<tr>
<td>Linda See</td>
<td>Research Scholar</td>
<td>Geodemographics, GIS</td>
</tr>
<tr>
<td>Marijn van der Velde</td>
<td>Research Scholar</td>
<td>Land-use, Climate Change Adaptation</td>
</tr>
<tr>
<td>Larry Willmore</td>
<td>Research Scholar</td>
<td>Economics, Social Policies</td>
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**Part Time**

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Field of expertise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andriy Bun</td>
<td>Research Scholar</td>
<td>Mathematical modeling of GHG emissions</td>
</tr>
<tr>
<td>Ying Cao</td>
<td>Research Scholar</td>
<td>Economics, Demography</td>
</tr>
<tr>
<td>Mykola Gusti</td>
<td>Research Scholar</td>
<td>Complex dynamic systems modeling</td>
</tr>
<tr>
<td>Georg Kindermann</td>
<td>Research Scholar</td>
<td>Forest Management, Land-use Change</td>
</tr>
<tr>
<td>Junguo Liu</td>
<td>Research Scholar</td>
<td>Hydrology, climate change impacts</td>
</tr>
<tr>
<td>Ian McCallum</td>
<td>Research Scholar</td>
<td>GIS, Remote sensing expert</td>
</tr>
<tr>
<td>Felicjan Rydzak</td>
<td>Research Scholar</td>
<td>Management, manufacturing engineering</td>
</tr>
<tr>
<td>Alexei Smirnov</td>
<td>Research Scholar</td>
<td>Control theory and optimization</td>
</tr>
<tr>
<td>Jana Szolgayová</td>
<td>Research Scholar</td>
<td>Applied Mathematics, Stochastic Optimization</td>
</tr>
<tr>
<td>Hugo Valin</td>
<td>Research Scholar</td>
<td>Environmental Management and Resource Economist</td>
</tr>
</tbody>
</table>

**Representative Recent Collaborating Institutions**

BOKU – University of Natural Resources and Applied Life Sciences and Technical University, Vienna (Austria); Directorate Environment DG-Research, European Commission; IGSNRR, Chinese Academy of Sciences; Peking University and Tsinghua University (China); Finnish
External Contracts and Grants that Extend into 2011 And Beyond

The total external funds for ESM-FOR amounted to Euro 2,350,483 in 2009 and Euro 2,204,216 in 2010.

Given the large number of contract and grants (>30) and their variety and distribution over the program’s research fields, they are clustered into groups so as to best identify their complementary contributions to IIASA’s strategy.

The projects related to the cluster “Global Earth Observation” (GEO) aim to improve the technical characteristics of remote sensing products and the current data sets needed for Earth systems and land use integrated modeling. For sustainable land and ecosystem management, the accurate and operational knowledge of land cover and biophysical indicators is crucial. The cluster is important and very relevant for IIASA’s Strategic and Research Plan as the projects help to substantially reduce uncertainty of the input information and results. Moreover, some of the projects are coordination projects that help to improve not only data flow and data access but also to optimize the whole information environment of FOR’s integrated modeling cluster (including models such as GLOBIOM, EPIC, BEWHERE, G4M). GEO contributes to the Food and Water theme as well as to Energy and Climate Change and also enables in-depth analysis in the Poverty area to be carried out. In particular the projects involve coordination and networking and will help improve IIASA’s visibility.

The “Ecosystem” cluster covers the study and management of ecosystem services, ranging from conservation of biodiversity to the provision of fresh water. In this area IIASA has substantial and unique strengths in integrated assessment of issues of competition for land and associated land resources. It directly addresses the area of Food and Water in collaboration with other IIASA programs. Furthermore IIASA occupies a unique niche in supporting the policy processes of REDD as well as ecosystem-based risk management in efforts against climate change. ESM–FOR’s integrated model cluster is currently one of the most competitive model clusters in terms of addressing the problem of sustainable (integrated) land management. In this area high visibility is being achieved both in terms of high-impact academic journal articles directly produced from the research networks connected to the projects and in terms of direct
policy impact. Many of the projects analyses are directly applied at national level, thereby serving IIASA NMO interests.

ESM–FOR’s contracts and grants under the “Climate Change” cluster, a number of which are held jointly with the Mitigation of Air Pollution and Greenhouse Gases (MAG) Program and many national institutions, reflect the program’s direct involvement in global climate change research on a European and global scale. ESM–FOR is involved partly in the production of land use change estimates for the IPCC AR5, conducts assessments of the co-benefits of the mitigation and adaptation strategies in terrestrial ecosystems management and is also connected to the leading Carbon and Climate Observing systems and linked networks. Through these projects ESM–FOR is currently at the forefront of assessing the biogeochemical role of ecosystems and impacts of climate extremes on ecosystem and ecosystem management using IIASA-based advanced systems analysis models and techniques.

ESM–FOR’s contracts and grants in the “Biomass, Energy, and Economic Assessment” cluster build on over a decade of risk and uncertainty–based decision-support tools for investment strategies. ESM–FOR conducts spatially explicit biomass systems assessments addressing issues of sustainability of supply and economic competitiveness given a number of technological development trajectories. IIASA’s ESM–FOR’s biomass assessments are used for policymaking in many NMO countries and are conducted in strong collaboration with other IIASA research programs contributing to all three problem areas.

ESM–FOR’s research contracts and grants in the “Agriculture, Food and Livestock” cluster have until now focused on the geographic explicit assessment of mitigation and adaptation strategies in climate change. More recently, under this cluster’s projects, ESM–FOR has developed a bottom-up economic partial equilibrium model with a detailed representation of agricultural production systems. In collaboration with ILRI and other project funds ESM–FOR is currently developing livestock systems transition scenarios to assess the impact of technological change in the agriculture and livestock sector on global food supply, human consumption patterns, strategy supporting undernourishment and secure water supplies (quantity and quality), and other environmental impacts. The livestock component of the IIASA GLOBIOM Model can be regarded as the most comprehensive supply system for livestock products globally. It has gained high visibility in many other research networks and led to invitations to participate in global agricultural assessment projects as well as stronger integration of IIASA with the CIGIAR system.

ESM–Land Use Change (LUC)

Program focus and relevance

The objective of the ESM– Land Use Change (LUC) Program is to produce policy-relevant, science-based analysis to secure future food and water provisioning while enhancing sustainability of land and water resources use.

ESM–LUC is establishing comprehensive integrated databases of land and water use and associated geophysical, ecological and socioeconomic dynamics. Consistent spatial data are essential for robust modeling and policy analysis. ESM–LUC’s focus on intelligent data and information systems responds to an internationally recognized lack of solid commitment to establishing and maintaining comprehensive information and monitoring services in soil and land use management.
Developing quantitative, spatially explicit, and detailed modeling and policy analysis tools is a core scientific goal of ESM–LUC. For instance, crop and livestock productivity, market access and the effects of climate are all highly location-specific.

The research combines spatially detailed modeling of land use options in diverse social and environmental conditions and accounts for physical and financial flows across multiple scales to accomplish global coverage and systems closure. The integrated modeling framework is applied in analyses of land use competition, responsible land development investment strategies, impacts of, and adaptation to, climate change, and issues of sustainable consumption to guide decision making toward improved and integrated resource use strategies.

In 2011 research within the integrated FOR and LUC ESM Program will address issues on the following major topics:

- Doubling world food provision and improving distribution;
- Water for food and agriculture;
- Mobilizing resources for the bio-based economy; and
- Climate change adaptation of food and water systems.

Achieving sustainable food security can only be realized within the overall framework of poverty eradication and involves many actors working together at national, regional and international levels. Research in ESM–LUC, aiming to explore critical factors in future food and water supply and distribution, will contribute to identifying policy options and strategies for improving human livelihoods, especially in the rural sector.

The land use sector both contributes to and is severely affected by climate change. Climate change is expected to have the most severe impacts in regions already short of water resources. Direct links to the Energy and Climate Change Area will be established, for instance, in the analysis of future land use changes, sustainable mobilization of biomass for energy uses, and the effective and equitable adaptation of food and water systems to climate change.

**Building on Current Program Expertise and Past Achievements**

ESM–LUC has a long-standing reputation for global, regional and national assessments of food security as affected by resource availability, socioeconomic and demographic developments, as well as climate change impacts. ESM–LUC also brings its internationally recognized experience regarding formulation and application of global and regional land use change scenarios; the European Biofuel Roadmap; Biofuels and Food Security; Rising Global Interest in Farmland; and land use scenarios for IPCC emission pathways.

ESM–LUC researchers have been the developers of a global agro-ecological zones (AEZ) database, modeling tools and an AEZ Web portal. Its core activities are based on a well tested integrated modeling framework comprising a spatially detailed ecophysiological model and bottom-up assessment of agricultural land and water use options (food and feed crops; biomass for energy use; fodder crops and pastures) and a regionalized general equilibrium model featuring the food and agriculture economy and its linkages to other sectors and human wellbeing. Downscaling/upscaling methodologies together with these two types of models form the basis of scenario evaluation, impact assessment, and policy analysis of food, agriculture, and land use options at the national, regional and global levels.
ESM–LUC scientists have established a lead position in developing new iterative Bayesian type procedures in down- and up-scaling, in multiple-scale data harmonization and assimilation, data-model fusion and multiple model fusion. Scaling, assimilation and fusion tools developed by ESM–LUC and its collaborators have been successfully applied at the global scale and in projects related to China and the EU.

Building on this strong foundation, ESM–LUC will further develop multi-scale data and information systems in collaboration with Chinese researchers, combine Intelligent Data-Model Fusion (Bayesian learning type of filter) with Markov Chain Monte Carlo techniques. It will improve the spatial land and water linkage; extending GAEZ to link with a hydrological model at the cropping zone/watershed level will permit water productivity, water governance and management efficiency to be assessed. The program will analyze the ways in which the entire food system, from production of farm inputs, through farm practice, to fork, can reduce dependence on non-renewable resources (such as energy for fertilizers, fuel for farm power, and food processing and distribution). Best practices in agriculture and land use for environmental efficiency and sustainability will be studied. Modeling and decision-support systems for robust management of risks associated with land use, agricultural production and food security will be developed. Research questions include regional indicators of sustainable agricultural development, robust investments in agricultural and rural activities and infrastructure, stability of agricultural markets operating under risks and uncertainties and design of financial risk mitigation instruments such as credits and insurance.

Five Recent Representative Research Publications


Four Representative Recent Policy Applications


Human Resources (excluding guest scholars)

**Full Time**

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Field of expertise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tatiana Ermolieva</td>
<td>Research Scholar</td>
<td>Mathematical modeling, decision analysis</td>
</tr>
<tr>
<td>Günther Fischer</td>
<td>Research Scholar</td>
<td>Mathematics, scenario development</td>
</tr>
<tr>
<td>Sylvia Prieler</td>
<td>Research Scholar</td>
<td>Land use change, GIS</td>
</tr>
<tr>
<td>Harrij van Velthuizen</td>
<td>Senior Research Scholar</td>
<td>Land resources ecology</td>
</tr>
<tr>
<td>David Wiberg</td>
<td>Research Scholar</td>
<td>Hydrology, water engineering</td>
</tr>
</tbody>
</table>

**Part Time**

<table>
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<tr>
<th>Name</th>
<th>Position</th>
<th>Field of expertise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eva Tothne Hisznyik</td>
<td>Research Scholar</td>
<td>Economics, statistics</td>
</tr>
<tr>
<td>Ferenc Toth</td>
<td>Senior Research Scholar</td>
<td>Economics</td>
</tr>
<tr>
<td>Laixiang Sun</td>
<td>Senior Research Scholar</td>
<td>Economics, mathematics</td>
</tr>
<tr>
<td>Geza Toth</td>
<td>Research Assistant</td>
<td>Natural resource management</td>
</tr>
</tbody>
</table>

**Representative Recent Collaborating Institutions**

Food and Agriculture Organization of the United Nations (FAO), Rome, Italy; United Nations Environment Programme (UNEP), Nairobi, Kenya; The World Bank, Washington D.C., USA; International Food Policy Research Institute (IFPRI), Washington D.C., USA; International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Andhra, Pradesh, India; World Soil Information (ISRIC), Wageningen, the Netherlands; Centre for World Food Studies (SOW-VU), Amsterdam, the Netherlands; Energy Research Centre of the Netherlands (ECN), Petten, the Netherlands, Ecowys, Utrecht, the Netherlands; Chinese Center for Agricultural Policy (CCAP), Chinese Academy of Sciences, Beijing, China; Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing, China; Shanghai Meteorological Bureau, Shanghai, China; Flemish Institute for Technological Research (VITO), Boeretang, Belgium; Institute of Economics and Forecasting (IEF), National Academy of Sciences, Kiev, Ukraine; Österreichische Bundesforste AG (ÖBF), Purkersdorf, Austria; European Commission Joint Research Centre (JRC), Ispra, Italy; Chalmers University of Technology, Department of Energy and Environment, Göteborg, Sweden; Fundación Circe, Natural Resources Division, Zaragoza (Spain).
External Contracts and Grants that Extend into 2011 and Beyond

The LUC component of ESM had external funding in the amount of Euro 390,928 in 2009 and Euro 387,025 in 2010.

ESM–LUC’s externally funded research contracts builds on and extends the programs leading role in land use and water data and modeling. Its largest contract, with the EU - DG Research, analyzes, quantifies and predicts the components of the current and future states of the global water cycles and related water resources, to evaluate their uncertainties, and to clarify the overall vulnerability of global water resources related to the main societal and economic sectors. The project provides IIASA with access to state-of-the-art hydrological data and methodologies, and helps advance the integration of these methodologies into our own modeling tools. Other contracts quantify scenario storylines in terms of drivers of water demand (population, GDP, land use and energy) and provides decision support for water policy and management.

At the core of another DG Research–funded project is the policy need to better integrate mainstream economic indicators with sustainable development objectives. Based on these analyses, recommendations for new indicator approaches will be proposed and strategies for implementing these approaches will be identified and developed in consultation with stakeholders.

EU policy demand provides funding to develop baseline data and methodology on land use and food system responses in support of EU reporting requirements for biofuels. ESM–LUC is also engaged in timely and relevant research on “Rising global interest in farmland” with and sponsored by the World Bank, to estimate spatially detailed land values and investment opportunities of importance to developing countries that are in the process of leasing or selling large tracts of their fertile agricultural land resources.

Sponsored by the European Bank for Reconstruction and Development, agricultural bio-energy feedstock potentials will be assessed for five Eastern European countries in the context of the project “Assessing the Market for Commercial use of Biomass for Heat and Power Generation in Belarus, Bulgaria, Romania, Turkey and Ukraine.”

ESM–LUC and FAO have developed a new comprehensive Harmonized World Soil Database (HWSD). Large volumes of recently collected regional and national updates of soil information were used for this state-of-the-art database. HWSD is a significant step forward to make global soil information freely available. Still more efforts are required to bring into HWSD the basic information materials and various soil databases available for North America, Western Africa, South Asia, and Australia. In close collaboration with FAO and ISRIC, further updating and expansion of HWSD is being planned for 2011.

On the occasion of completing a major update and expansion of the Global Agro-ecological Assessment for Agriculture (GAEZ), an expert consultation was held in mid-2010 at the FAO headquarters in Rome. The advice of expert consultation entailed the establishment of a GAEZ Consortium shared by IIASA, FAO, IFPRI, World Bank and Purdue University. The Consortium agreed to take charge and share the burden of further AEZ development and dissemination of GAEZ products. Expected activities in 2011 and 2012 include updating the underlying environmental databases, establishing a user community network, and providing workshops for GAEZ users.
Evolution and Ecology Program

Program Focus and Relevance

IIASA’s Evolution and Ecology (EEP) Program analyzes and forecasts how ecological and evolutionary dynamics shape populations, communities and ecosystems. Specific challenges addressed range from assessing and managing human-induced evolutionary changes in exploited fish stocks, to understanding the impact of environmental disturbances on the structure and functioning of food webs, and to fostering cooperation in groups of agents. Together with its network of international collaborators, the program is driving the development and application of adaptive dynamics theory, a framework recognized by many as the most versatile tool currently available for linking the ecological and evolutionary consequences of environmental change. Based on a two-pronged attack through applied and methodological research, the program establishes bridges between fundamental and policy-oriented, theoretical and empirical, biological and mathematical, and analytical and numerical approaches.

EEP promotes the systems analysis of living systems by contributing to IIASA’s characteristic research approach, which is science-based, problem-driven and solution-oriented, integrated and interdisciplinary, as well as independent and international. If human interventions directed at sustainable development and responsible conservation are to be successful, they must account for the ecological and evolutionary dimensions of anthropogenic environmental change. Moreover, analyzing complex adaptive systems requires dealing with nonlinear feedbacks, non-equilibrium states, discontinuities and break points, collective phenomena, systemic transitions, behavioral dynamics, as well as with multi-level and multi-scale interactions among processes and agents. Modern approaches inspired by biological systems are often more suited to meeting these challenges than traditional methods developed for physical systems. This potential translates into a research agenda that responds to a range of key challenges indicated in IIASA’s new strategic plan, including achieving a stable world food supply, analyzing the impacts of environmental degradation on ecosystem services, understanding inequities and how to reduce them, protecting species and biodiversity, finding robust and adaptive solutions, and modeling extreme destabilizing events and systemic risks.

Building on Current Program Expertise and Past Achievements

EEP brings together methods and perspectives from biology, physics, engineering, computer science and applied mathematics. Recently, socioeconomic aspects and elements of decision analysis were added to the program’s research agenda. EEP’s current staff have published more than 230 IIASA-affiliated journal articles recognized by the ISI Web of Science by Thompson Reuters, including 21 in Nature and Science. These publications have been cited more than 6,600 times, resulting in an h-index of 41.

EEP’s expertise is particularly strong in three areas of research. First, within less than a decade EEP has built up at IIASA considerable know-how on fisheries and marine ecosystems. Nowadays, IIASA is a world leader in research on fisheries-induced evolution. Second, EEP’s research on the evolution of cooperation has reached the highest international level in terms of publications and recognition. Third, EEP is committed to methodological pluralism and
development, and is among the world leaders in a few of the resultant fields. EEP thus develops and applies a broad portfolio of tools, including structured and unstructured population dynamics, epidemiological dynamics, food-web dynamics, spatiotemporal point processes, reaction-diffusion dynamics, moment-based approximations, graph-based dynamics; evolutionary game theory, adaptive dynamics theory, co-evolutionary dynamics, optimization models for adaptive strategies, life-history theory, dynamic programming, genetic dynamics, eco-genetic models; nonlinear dynamics, stochastic processes, individual-based and agent-based models, bifurcation theory and phase transitions, model-approximation techniques, generalized linear models, neural networks, and game theory.

During 2011–2015, EEP will contribute to three of IIASA’s six research themes. Work on the integrated assessment of fishery systems and on evolutionarily sustainable consumption will examine options and challenges for the development of aquatic food resources (Food and Water Area). Work on the equitable governance of common goods will investigate how top-down regulations for managing common goods or open access resources can be improved by accounting for stakeholder conflicts and by scaling up the successful characteristics of self-organized and resilient bottom-up governance (Poverty and Equity Area). Studies on the eco-evolutionary dynamics of living systems, on systemic risk and network dynamics, and on integrating structure and functioning in models of plant ecosystems under global change are intended to open up new methodological avenues for the applied systems analysis of biodiversity, tangled interactions, and ecosystem dynamics (Advanced Systems Analysis Program). In addition, the last project’s process-based modeling approach will enable novel features in next-generation dynamic global vegetation models, which are instrumental for assessing climate impacts (Energy and Climate Change Area). Together, these projects will show how innovative methods inspired by the dynamics of living systems invigorate and integrate important facets of modern applied systems analysis.

**Five Representative Recent Research Publications**


**Five Representative Recent Policy Applications**


**Human Resources (excluding guest scholars)**

**Full Time**

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Field of expertise</th>
</tr>
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<tbody>
<tr>
<td>Ulf Dieckmann</td>
<td>Program Leader</td>
<td>Biology</td>
</tr>
<tr>
<td>Varvara Fazalova</td>
<td>Research Assistant</td>
<td>Biology</td>
</tr>
<tr>
<td>Chiho Kaito</td>
<td>Research Assistant</td>
<td>Computer Science</td>
</tr>
<tr>
<td>Agnes Rettelbach</td>
<td>Research Assistant</td>
<td>Biology</td>
</tr>
<tr>
<td>Tatsuya Sasaki</td>
<td>Research Scholar</td>
<td>Mathematics</td>
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</table>

**Part Time**

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<tr>
<th>Name</th>
<th>Position</th>
<th>Field of expertise</th>
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</thead>
<tbody>
<tr>
<td>Åke Brännström</td>
<td>Research Associate</td>
<td>Mathematics</td>
</tr>
<tr>
<td>Mikko Heino</td>
<td>Research Associate</td>
<td>Biology</td>
</tr>
<tr>
<td>Rupert Mazzucco</td>
<td>Research Scholar</td>
<td>Physics</td>
</tr>
<tr>
<td>Hans Metz</td>
<td>Research Associate</td>
<td>Biology</td>
</tr>
<tr>
<td>Sergio Rinaldi</td>
<td>Research Associate</td>
<td>Engineering</td>
</tr>
<tr>
<td>Akira Sasaki</td>
<td>Research Associate</td>
<td>Biology</td>
</tr>
<tr>
<td>Karl Sigmund</td>
<td>Research Associate</td>
<td>Mathematics</td>
</tr>
</tbody>
</table>

**Representative Recent Collaborating Institutions**

Department of Mathematics, University of Vienna, Austria; Max F. Perutz Laboratories, University of Vienna, Austria; Department of Fisheries and Oceans, St. John’s, Canada; Department of Zoology, University of British Columbia, Vancouver, Canada; Department of Theoretical Biology, Institute of Entomology, Czech Academy of Sciences, Prague, Czech Republic; Department of Mathematics, University of Turku, Finland; Fishery Resources Laboratory, French Institute of Research for the Exploitation of the Sea, Port-en-Bessin, France; Leibniz Institute for Freshwater Ecology and Inland Fisheries, Berlin, Germany; Department of Biological Physics & Department of Plant Taxonomy and Ecology, Eötvös Lorand University,
Budapest, Hungary; Hólar University College, Hólar, Iceland; Marine Research Institute, Reykjavik, Iceland; Department of Electronics and Information, Technical University, Milano, Italy; Department of Evolutionary Study of Biosystems, Graduate University of Advanced Studies, Hayama, Japan; Faculty of Applied Biological Sciences, Gifu University, Japan; Division of Biological Sciences, Pusan National University, Korea; Department of Marine Biology, Pukyong National University, Busan, Korea; Department of Biology, University of Bergen, Norway; Institute of Marine Research, Bergen, Norway; Centre for Ecological and Evolutionary Synthesis, Department of Biology, University of Oslo, Norway; Southern Scientific Centre of the Russian Academy of Sciences, Rostov-on-Don, Russia; Department of Mathematics and Mathematical Statistics, Umeå University, Sweden; Department of Zoology, Stockholm University, Sweden; Department of Behavioural Ecology, Zoological Institute, University of Bern, Switzerland; Institute for Marine Resources and Ecosystem Studies, Wageningen University and Research Centre, IJmuiden, The Netherlands; Freshwater Fisheries Laboratory, Pitlochry, UK; Program for Evolutionary Dynamics, Harvard University, Cambridge, USA

External Contracts and Grants Extending to 2011 and Beyond

EEP’s external funding was Euro 1,103,403 in 2009 and Euro 487,638 in 2010.

EEP currently holds a grant supporting its research focus on the “Evolution of Cooperation.” With respect to the new strategic plan and research plan, this grant will support research on dynamic games, behavioral economics, and the equitable governance of common goods.
The Risk Policy and Vulnerability (RPV) Program combines elements of the previous Risk and Vulnerability (RAV) Program and the Health and Global Change (HGC) Project.

**RPV–Risk and Vulnerability (RAV)**

**Program Focus and Relevance**

RPV–RAV combines quantitative methods for modeling and analyzing systems with a suite of quantitative and qualitative approaches to policy analysis. Its objective is to contribute to decreasing the vulnerability of economic, ecological and social systems to stresses imposed by global change and by policies designed to cope with global change. In pursuing this objective, RPV–RAV decreases vulnerability, with a special focus on the vulnerability of the poor.

RPV–RAV is well positioned to contribute to IIASA’s new strategic areas: (i) to the Poverty and Equity Area with staff expertise on catastrophic risk and poverty traps, RAV’s work on building catastrophe safety nets for the most vulnerable, and its history of workshops and publications on equity and fairness; (ii) to the Energy and Climate Change Area by analyzing mitigation and adaptation alternatives using methodologies that combine systems modeling with the appraisal of economic, political and institutional dynamics; and (iii) to the Food and Water Area through its work on resilience and adaptive capacity of the social-ecological systems in river basins. Moreover, RPV–RAV intends to be an active participant in IIASA’s Policy and Governance Forum, starting with a plan to convene stakeholders (the UNFCCC secretariat, country parties, insurers and NGOs) with a view to implementing the proposals by RPV–RAV (as part of the Munich Climate Insurance Initiative) to include insurance instruments in a climate adaptation regime.

**Building on Current Program Expertise and Past Achievements**

RPV–RAV’s work has been divided into three working groups.

The “Disasters, adaptation and development” group makes use of advanced methods, including vulnerability and risk assessment, decision making under risk and uncertainty, extreme value theory, economic analysis of risk management and adaptation, and participatory and communication tools, to support risk management of climate-related and geophysical hazards. With its CATSIM model, RPV–RAV has advised over 20 developing country governments on how to prepare for extreme events. Based on its work on safety nets for the most vulnerable, RPV–RAV has influentially proposed a Climate Risk Finance Facility in the context of the climate adaptation negotiations.

The “Decisions and governance” group analyzes processes of decision making under uncertainty in order to identify robust policy approaches to managing risk. Substantively, the
The “Water and resilience” group has developed a capacity for designing stakeholder-driven dialogs, aided by systems modeling and games, with recent applications in the Tisza and Odra river basins. The purpose has been to elicit local knowledge and identify policy options that enhance the resilience and adaptive capacity of the social-ecological systems in these river basins.

The program’s methodological expertise lies in the qualitative and quantitative analysis of social and social-ecological systems. Its extended core staff (currently 20 persons) represent eight disciplines—statistics, physics, economics, geography, sociology, ecology, public policy and anthropology—working together on problem-driven interdisciplinary research.

RPV–RAV researchers have developed and continue to apply two core models. The CATSIM model, which examines financial and other coping strategies for governments, merges risk analysis of extreme events with macro- and micro-economic analysis of agents’ coping capacity. The MARGE model is used to develop scenarios of renewable energy investment in the Mediterranean region. Beyond models, the program has extensive experience in applied policy analysis; staff have expertise in such techniques as risk analysis, cost-benefit analysis, systems modeling, multiple-perspective approaches (stemming from cultural theory), multi-attribute decision analysis, and the creative use of these approaches in stakeholder-led policy processes. RPV–RAV’s influential policy advice on climate change and social safety nets, for example, builds on extensive participatory case work in transition and developing countries. The program is also well known for its use of systems modeling in stakeholder settings.

Five Recent Representative Research Publications


Five Recent Representative Policy Applications


Human Resources (excluding guest scholars)

**Full Time**

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Field of expertise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bayer, Joanne</td>
<td>Program Leader</td>
<td>Uncertainty and Disaster Risk Management</td>
</tr>
<tr>
<td>Damerau, Kerstin</td>
<td>Research Assistant</td>
<td>Climate change, renewable energies</td>
</tr>
<tr>
<td>Hanger, Susanne</td>
<td>Research Assistant</td>
<td>Geography</td>
</tr>
<tr>
<td>Hochrainer-Stigler,</td>
<td>Research Scholar</td>
<td>Quantitative risk management, Advanced statistical modeling</td>
</tr>
<tr>
<td>Stefan</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patt, Anthony</td>
<td>Senior Research Scholar</td>
<td>Climate change policy</td>
</tr>
<tr>
<td>Pfenninger, Stefan</td>
<td>Research Assistant</td>
<td>Energy and climate change policy</td>
</tr>
<tr>
<td>Scolobig, Anna</td>
<td>Research Scholar</td>
<td>Risk perception, risk communication, social vulnerability</td>
</tr>
<tr>
<td>Sharma, Upasna</td>
<td>Post-doc Research Scholar</td>
<td>Adaptation to climate change, disaster management</td>
</tr>
<tr>
<td>Sendzimir, Jan</td>
<td>Senior Research Scholar</td>
<td>Systems Ecology</td>
</tr>
<tr>
<td>Williges, Keith</td>
<td>Research Associate</td>
<td>Renewable energy / modeling</td>
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</table>

**Part Time**

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Field of expertise</th>
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</thead>
<tbody>
<tr>
<td>Amendola, Anniello</td>
<td>Research Scholar</td>
<td>Engineering</td>
</tr>
<tr>
<td>Komendantova, Nadejda</td>
<td>Research Scholar</td>
<td>Renewable energy and energy efficiency</td>
</tr>
<tr>
<td>Lasut-Dubel, Anna</td>
<td>Research Scholar</td>
<td>Management, economic analysis</td>
</tr>
<tr>
<td>Lilliestam, Karl</td>
<td>Research Assistant</td>
<td>Renewable electricity, energy security, energy policy</td>
</tr>
<tr>
<td>Johari</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnuszewski, Piotr</td>
<td>Research Scholar</td>
<td>Computer Modeling, Adaptive Management</td>
</tr>
<tr>
<td>Me切尔, Reinhard</td>
<td>Senior Research Scholar</td>
<td>Natural disaster risk management, development and ecological economics</td>
</tr>
<tr>
<td>Pflug, Georg</td>
<td>Research Scholar</td>
<td>Statistics and Operations Research, Insurance and Finance</td>
</tr>
<tr>
<td>Schröter, Dagmar</td>
<td>Research Scholar</td>
<td>Ecology</td>
</tr>
<tr>
<td>Thompson, Michael</td>
<td>Senior Research Scholar</td>
<td>Social anthropology, Governance/Risk</td>
</tr>
</tbody>
</table>
Representative Recent Collaborating Institutions

Potsdam Institute for Climate Impact Research, Munich Re, University of Oldenburg, Stockholm Environment Institute, Kings College London, Tyndall Centre for Climate Research, Arizona State University, Oxfam America, United Nations Development Programme, Technology Information, Forecasting and Assessment Council, University of Cape Town, University Eduardo Mondlane, Transparency International, World Bank, London School of Economics, Free University of Amsterdam, Vienna University of Economics and Business, UNEP, Indian Institute of Technology, Asian Disaster Preparedness centre, Overseas Development Institute, Lund University, All India Disaster Mitigation Institute.

External Contracts and Grants that Extend into 2011 and Beyond

External funding for RPV–RAV amounted to Euro 550,924 in 2009 and Euro 678,869 in 2010. Subjects include:

- Developing generic risk-management strategies for reducing landslide risk;
- Leading EU integrated research on water and agriculture in the face of climate change;
- Developing a European decision-support system for climate change adaptation;
- Developing new methods to integrate methods for multi-risk assessment, accounting for cascading hazards and time dependent vulnerability;
- Examining incongruent model results on the potential of renewable energy for reaching emission levels consistent with climate protection; and
- Carrying out an assessment of disaster micro-insurance in South-east Asia.

While primarily focused in Europe, many of the approaches developed will be highly relevant to the Poverty and Equity Area—all the more so given numerous case studies in developing countries across Asia, Africa and Latin America. It should be noted that the program’s external projects contribute equally to the fields of the Energy and Climate Change Area as well as the Food and Water Area.

RPV—Health and Global Change (HGC)

The Health and Global Change (HGC) Special Project will be phased out in 2011. Some of its activities will continue in RPV and in the Poverty and Equity Area. There is also an exploratory activity “Health and Wellbeing in the Urban Environment,” which is spearheaded by ICSU with collaboration from IIASA.

Program Focus and Relevance

The objective of RPV–HGC is to contribute policy-relevant research that will help improve health in developing countries and the countries of the former Soviet Union. Health is broadly perceived to be lagging in these countries. Necessary institutional reforms are slow in coming and access to reasonable-quality health care remains low even in the context of rapid economic growth. Millennium Development Goals related to health are proving to be among the most difficult to achieve.
The project’s main focus has been on systems modeling approaches to health, with emphasis on applied policy work. Among the areas of interest and substantive expertise within the RPV-HGC are: infectious disease, including malaria, influenza and TB; linkages between health and poverty; urbanization and health; external causes of death (suicide, homicide, accidents); global public good aspects of health, and social protection. A second major focus is to strengthen the project’s international network through collaborations with various research and policy organizations, mostly in policy analysis and evaluation.

As RPV–HGC has developed a methodological niche in the application of micro-simulation modeling of health, poverty and social safety nets, it sees its role as an integrative one in which empirical relationships derived from a range of IIASA programs—the Mitigation of Air Pollution and Greenhouse Gases (MAG) Program, the Energy (ENE) Program, the World Population (POP) Program and others—can be integrated into a single multi-dimensional model of poverty.

Building on Current Program Expertise and Past Achievements

Building on its network of part-time researchers, the project has established IIASA as a credible player in the area of health and global change:

- It has contributed to interdisciplinary research and policy dialog on global public good aspects of health, including the organization of a major international conference on pandemic influenza.
- Project staff are recognized authorities in the evaluation of international development cooperation in countries such as Russia, China, India and elsewhere in the developing world.
- HGC’s work in micro-simulation modeling of links between poverty, equity, health and global change has led to a significant emerging partnership with the Institute for Economic Growth in Delhi, which aims to combine capacity building with innovative research into the links between the various MDGs. A Memorandum of Understanding has been concluded with the Institute for Population Research and the Institute for Population Studies at Peking University. Through exchanges of researchers and joint research on health, disability and the environment in China, IIASA’s relationship with China will be deepened. This relationship represents an ideal combination of IIASA’s methodological capacity with NMO country researchers with national expertise and access to data.
- The project is the key partner of the International Council for Science (ICSU) in development of their science plan for “Health and Wellbeing in the Changing Urban Environment,” and continues to maintain an important research focus on the linkages between health and urban processes in a variety of contexts.

Looking forward, new internal arrangements to allow this work to continue at IIASA are being considered. This includes integration of the micro-simulation work in the Poverty and Equity Area and establishing a collaboration with ICSU on health and wellbeing in the urban environment.

Five Representative Recent Research Publications


**Five Representative Recent Policy Applications**


**Human resources (excluding guest scholars)**

<table>
<thead>
<tr>
<th>Full Time</th>
<th>Position</th>
<th>Field of expertise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jose Siri</td>
<td>IIASA post-doc</td>
<td>Epidemiology</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part Time</th>
<th>Position</th>
<th>Field of expertise</th>
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<tbody>
<tr>
<td>Landis MacKellar</td>
<td>Research Scholar</td>
<td>Economics, development strategy evaluation</td>
</tr>
<tr>
<td>Andrew Noymer</td>
<td>Research Scholar</td>
<td>Sociology, infectious disease</td>
</tr>
<tr>
<td>Martin Spielauer</td>
<td>Research Scholar</td>
<td>Microsimulation, modeling</td>
</tr>
<tr>
<td>Zachary Brown</td>
<td>Returning Peccei Scholar</td>
<td>Environmental Economics</td>
</tr>
<tr>
<td>Steven Ney</td>
<td>Collaborator</td>
<td>Political Science</td>
</tr>
<tr>
<td>David Horlacher</td>
<td>Collaborator</td>
<td>Economics</td>
</tr>
</tbody>
</table>

**Representative Collaborating Institutions**

Institute for Economic Growth (IEG), Delhi, India; Institute for Population Research, Peking University; Institute for Population and Social Research, Mahidol University; International Council for Science (ICSU), Paris, France; Statistics Canada Fogarty International Center, U.S. National Institutes of Health Middlebury College, Middlebury, Vermont; Center for the Study of Health in Societies in Transition (SCOHOST), University of South Stockholm, Stockholm, Sweden.
External Contracts and Grants that Extend into 2011 And Beyond

Landis MacKellar is team leader of a seven-person team charged with evaluating roughly 100 projects financed by the United Nations Democracy Fund (UNDEF). IIASA’s contribution will consist of methodological support and quality insurance. The prime contract is held by Transtec (www.transtec.be) and IIASA is a sub-contractor for about Euro 144,000. The projects, typically of the order of USD 250,000 each, support civil society organizations in the poorest countries of the world. Through this activity, IIASA will establish networks and strengthen credibility in the new area of Poverty and Equity.
World Population Program

Program Focus and Relevance

The objective of IIASA’s World Population (POP) Program is to contribute to addressing the challenges of global change by providing scientific analysis of the quantitative aspects of human population. POP is particularly committed to advanced methods of population projection, with special emphasis on interactions between population and human capital. Its activities have been equally divided between developing countries, where rapid population growth is the traditional concern, and developed countries that must cope with population aging. POP also contributes to basic methodological research, as well as being a major player in international population policy.

In all human actions, including economic production, the building of institutions and human impacts on the environment, people are the agents of change. Hence, there is not one single research area defined in IIASA’s Strategic Plan in which the actions of people would not be of key importance. None of these actions and the resulting changes that are at the heart of the IIASA research agenda can happen without people causing them. The kind of actions taken depend, among many other factors, decisively on the changing size of the population and, in many instances even more importantly, on the changing composition of populations according to certain key properties (such as age, sex, level of education and others). In its research, POP primarily focuses on those properties that have been shown to be of significant importance to the research areas of IIASA and that can be quantitatively assessed and hence modeled in their dynamics of change.

In particular, POP will contribute to Poverty and Equity Area with a cross-cutting project “Toward an integrated approach to poverty alleviation: Synthesis and systems models,” in which POP will address the interactions between poverty, education and health. POP is also engaged in applying its human capital data to projecting economic growth, an endeavor which will generate estimates that will be of relevance throughout the Institute.

Building on Current Program Expertise and Past Achievements

Through its focus on projections, POP has been a key source of the overall shift of policy concern from population growth to population aging. A series of articles published in Nature established that world population growth is likely to come to an end and that global population aging is in the process of accelerating. POP has also recently published path-breaking methodological research on the measurement of life expectancy. Through its combination of multi-state population projection approaches and education data, POP has assembled a unique data set on human capital, both historical and projected. Analyzed by econometricians, this new data has allowed economists to establish a much closer relationship between human capital and growth than was previously possible.

The credibility of its research has allowed POP to provide science-based policy-relevant information at the highest level to national governments, UN agencies, the European Commission, NGOs, and the private sector.
Over the coming years POP will try to further strengthen and advance its role in international population projections both through methodological development and new applications and also to enter the most challenging new field of trying to forecast societies’ future adaptive capacities to climate change. The latter is the topic of an European Research Council (ERC) Advanced Grant (2.5 million Euros for 2009–2014) recently won by Wolfgang Lutz. Further applications of multi-state population projections to new substantive issues, such as changes in the religious composition of the population, aging and productivity, and other properties that systematically vary along age or cohort lines are the topic of an ERC Starting Grant (1 million Euros for 2009–2014) won by Vegard Skirbekk.

In terms of methods used, POP will rely on a combination of already proven and innovative approaches: for modeling and projecting the dynamics of change of populations according to these properties, the methods of multi-state population projections which were developed at IIASA during the 1970s and 1980s and are now a key ingredient of the state-of-the-art probabilistic population toolbox will mostly be used, as well as continuing to apply methods of probabilistic population projects, which have been developed at IIASA more recently. Systems-analytical tools and methods will be used for studying population-development-environment interactions.

Formally, research by POP will be structured into four core projects.

• “IIASA–Oxford science-based projections by age, sex and level of education for all countries in the world.” This major new effort (mostly funded by the ERC Advanced Grant) brings two essential innovations: it will involve a major international peer review and scientific evaluation exercise (with more than 1,000 experts around the world) of the assumptions to be made and projections produced not only by age and sex but also by level of educational attainment for all countries.

• The “Age and Cohort Change (ACC)” project will carry out the ERC Starting Grant project as described above.

• The project on “Differential vulnerability and future adaptive capacity” (covered by the ERC Advanced Grant) will be a very ambitious effort to first empirically study the differential vulnerability by age, sex, education and other properties to disasters and other similar events expected as a consequence of climate change, and then to project them into the longer-term future.

• The “Future of human reproduction” project will systematically and in a truly interdisciplinary way (from medicine to evolutionary anthropology to economics to philosophy) address what we know about the future course of fertility in low-fertility settings. In other words, it will address the question: will people always want to have children and how low can fertility fall?

In addition there will be two concrete collaborative projects in which POP will play a key role: (i) the diffusion of new technologies among populations; and (ii) population-education-poverty-equity (PEPE) interactions.

Overall, for the coming years the aspiration is to have some visible impact in defining a new international population policy paradigm (“human capital development” i.e., adding the quality dimension to the study of human numbers). Here the main focus lies on studying the dynamics of global population change in its interactions with changing social, economic and environmental conditions. Special emphasis is given to the modeling of the dynamics of human capital formation, including its reconstruction and projections for as many countries as possible.
Five Representative Recent Research Publications


Five Representative Recent Policy Applications


Human Resources (excluding guest scholars)

**Full time**

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Field of expertise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samir KC</td>
<td>Research Scholar</td>
<td>Demography</td>
</tr>
<tr>
<td>Vegard Skirbekk</td>
<td>Project Leader</td>
<td>Economics</td>
</tr>
<tr>
<td>Marcin Stonawski</td>
<td>Research Assistant</td>
<td>Demography</td>
</tr>
<tr>
<td>Daniela Weber</td>
<td>Research Assistant</td>
<td>Applied mathematics</td>
</tr>
<tr>
<td>Regina Fuchs</td>
<td>Research Assistant</td>
<td>Demography</td>
</tr>
</tbody>
</table>

**Part Time**

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<tr>
<th>Name</th>
<th>Position</th>
<th>Field of expertise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bilal Barakat</td>
<td>Research Scholar</td>
<td>Mathematical demography</td>
</tr>
<tr>
<td>Stuart Basten</td>
<td>Research Scholar</td>
<td>Historical demography</td>
</tr>
<tr>
<td>Jesus Crespo Cuaresma</td>
<td>Research Scholar</td>
<td>Economics</td>
</tr>
<tr>
<td>Anne Goujon</td>
<td>Research Scholar</td>
<td>Demography</td>
</tr>
<tr>
<td>Harold Lentzner</td>
<td>Research Scholar (Associate)</td>
<td>Demography and epidemiology</td>
</tr>
</tbody>
</table>
Representative Recent Collaborating Institutions

Asian MetaCentre for Population and Sustainable Development Analysis, Singapore; College of Population Studies, Chulalongkorn University, Bangkok, Thailand; Department of Global Health and Population, Harvard University, Cambridge, MA, USA; Department for Social Statistics, Statistics Norway, Oslo, Norway; Departments of Economics and History, Stony Brook University, Stony Brook, NY, USA; Institute for Futures Studies, Stockholm, Sweden; Institute of Population Research, Peking University, Beijing, PR China; Institute for Social and Economic Change (ISEC), Bangalore, India; Netherlands Interdisciplinary Demographic Institute, The Hague, The Netherlands; Nihon University, Tokyo, Japan; Oxford Institute of Ageing, Oxford, UK; Pennsylvania State University, University Park, PA, USA; Pew Research Center, Washington, DC, USA; Statistics Canada, Ottawa, Canada; University of Oslo, Norway; Vienna Institute of Demography (VID), Austrian Academy of Sciences; Vienna University of Economics and Business Administration (WU).

External Contracts and Grants that Extend into 2011 And Beyond

POP received external funds in the amount of Euro 386,396 in 2001 and Euro 738,860 in 2010.

POP’s externally funded research applies and helps to build on the program’s expertise in multi-state population projection. A major ERC research project is right at the heart of IIASA’s new Strategic Plan. It has not been in response to a specific thematic call but has been strategically developed by Wolfgang Lutz to reach thematically across many of IIASA’s research areas. A key component of the project is a new set of science-based global population projections (on the country level, including states for China and India), not only by age and sex but also by level of educational attainment. Hence, this will be a basis for the analysis of population as a driver in all other IIASA programs and thematic areas as defined by the Strategic Plan. Without this extra funding from the ERC, IIASA would not have been able to produce such new science-based projections.

A second ERC-funded project complements the core research agenda of the World Population Program as described in the new Strategic Plan in two important ways: (i) it extends the properties of the population that are projected beyond age, sex and education to include such issues as religious affiliation, cognitive performance, value orientation, and others; and (ii) it gives particular attention to changes across cohorts and to the usual age and period which is an important methodological contribution to the Driver of Global Transformations component of the Strategic Plan. As an ERC project, it does not respond to a thematic call, but was defined strategically by the Principal Investigator.

This third research grant, from the Pew Research Center, is simply an addition to the ACC project (listed above), deepening the work in the field of religion projections.
Program Focus and Relevance

The strategic goal of the Transition to New Technologies (TNT) Program is to further the understanding of the patterns, drivers, constraints and impacts of technological change, particularly in the areas that are key for framing global sustainability conditions (such as climate change) and to disseminate policy-relevant research findings through high-level global forums and participation in major international scientific assessments.

In terms of systems hierarchy, technological change arises from the spatial and temporal diffusion of individual innovations all the way up to the emergence of new technological combinations that could fundamentally redefine products, services and even entire industries and markets. TNT’s strategic research goal consequently focuses on the systemic aspects of technological change and draws on empirical case studies, novel modeling approaches, as well as scenario studies and robustness analysis to inform technology policy choices from a systemic perspective. A key unifying strategic question addressed by TNT research is to answer what determines the rates of change of individual technologies as well as of entire technology systems in response to the interplay of endogenous (e.g., innovation and market uncertainties) as well as policy (e.g., innovation push and demand pull) variables.

A final objective of TNT is to maximize the visibility of its small in-house research staff through participation in a few, key international assessments and collaborative activities, most notably the IPCC.

Work in TNT will complement work in the three global problem areas described in IIASA’s Strategic Plan with “stand alone” basic research on technological drivers. While there will be a degree of alignment, TNT, like the World Population (POP) Program, will pursue a vigorous research agenda of its own. As a result technology research at IIASA will be conducted in three areas: (i) basic technology-specific research within TNT; (ii) basic research on exploring the interlinkages between the two fundamental drivers outlined in IIASA’s strategic plan, namely, population and technology (collaborative POP-TNT research on the relationship between human and social capital on technology diffusion); and (iii) applied research on selected strategic technologies in collaboration with the three problem areas Energy and Climate Change, Food and Water, and Poverty and Equity.

Building on Current Program Expertise and Past Achievements

TNT has, in the past, focused research on a few strategically important technology areas, in particular energy and climate-related technologies. It has maximized internal collaborative linkages and hence synergies with the Greenhouse Gas Initiative (GGI) and the Energy (ENE) Program and given high emphasis to major international scientific assessments as main networking and communication platforms for research and policy findings, most notably via the IPCC and the Global Energy Assessment (GEA). The program has had a substantive research strategy that focuses on prototyping of novel modeling concepts and initiating “gap filling” research in critical areas (e.g., agent-based models of technological complexity, spatially
explicit modeling of socioeconomic phenomena in order to advance the state-of-art of emission “downscaling” techniques, or analysis of technologies exhibiting negative returns to “learning-by-doing”). These strategic choices inevitably also entail tradeoffs: a focused research agenda on few critical technologies limits the potential to advance research in other technology areas of interest (e.g., the Internet and the digital divide), prototyping model development cycles limit the potential for long-term model maintenance, training and wide dissemination, and the focus on few, major international assessment limits the potential to reach out to numerous smaller research networks/communities within IIASA NMO countries.

In the next five-year cycle, TNT’s research aims to develop an improved understanding of the determinants of the rates of change of individual technologies as well as of entire technology systems that could constitute important constraints in addressing the policy challenges examined in IIASA's three problem areas. Empirical case studies as well as technology "meta-analysis" will feed into new modeling approaches of technological change with an emphasis on the treatment of technological uncertainty and spatial and actor heterogeneity. In turn the collaborative research on specific case studies will constitute a direct TNT input to IIASA's three problem areas, and insights gained from technology modeling studies within TNT are anticipated to become incorporated into policy models, particularly in the Energy and Climate Change Area.

IIASA is uniquely positioned because of its accumulated expertise and data, as well as international research networks in the area of technology studies, which allow it to rapidly explore possible consequences of technological discontinuities and “surprises” (such as the commercial availability of methane hydrates. IIASA researchers have also been leading in the development of concepts that are core to the theory of induced innovation. Their leading role has been recognized inter alia by being nominated to author the corresponding chapters on technology innovation in the latest (2007) IPCC assessment report as well as in the ongoing Global Energy Assessment (GEA). The long-standing focus of technology research of the TNT Program on empirical and historical case studies of technological change provides a unique data source and has already enabled highly innovative “meta-analysis” of a diversity of technological change patterns that nonetheless reveal striking regularity in their scaling behavior (cf. Wilson, 2009). Last but not least, IIASA researchers are widely recognized for their novel modeling approaches that have shed new light on the dynamics of large-scale technology systems. For instance, a series of models developed by TNT has advanced the state of the art in the modeling of uncertain increasing returns. Subsequent efforts have focused on developing alternative modeling approaches using agent-based and spatially explicit modeling techniques to represent heterogeneity.

**Five Representative Recent Research Publications**


Wilson, C. (2009). Meta-analysis of unit and industry scaling dynamics in energy technologies and climate change mitigation scenarios. IR-09-29, IIASA, Laxenburg, Austria.

Five Representative Recent Policy Applications


Human Resources (excluding guest scholars)

Full Time

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Field of expertise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuno Bento</td>
<td>Research Scholar (starting 2011)</td>
<td>Energy, transport technologies</td>
</tr>
</tbody>
</table>

Part Time

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Field of expertise</th>
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</thead>
<tbody>
<tr>
<td>Arnulf Grubler</td>
<td>Acting Program Leader/ Senior Research Scholar</td>
<td>Technology history and policy, energy</td>
</tr>
<tr>
<td>Peter Kolp</td>
<td>Professional</td>
<td>IT and Programming</td>
</tr>
<tr>
<td>Tiejun Ma</td>
<td>Research Scholar</td>
<td>Mathematics, agent-based modeling</td>
</tr>
<tr>
<td>Nebojsa Nakicenovic</td>
<td>Senior Research Scholar</td>
<td>Technology policy, energy, climate change</td>
</tr>
<tr>
<td>Keywan Riahi</td>
<td>Senior Research Scholar</td>
<td>Energy, climate change, policy modeling</td>
</tr>
</tbody>
</table>

Representative Recent Collaborating Institutions

Colegio Mexico (Mexico); DLR (Germany); ERI (China); Global Carbon Project (GCP, Tsukuba, Japan); IIED (Canada, UK); Imperial College (UK); IPCC (Geneva, Switzerland); Lund University (Sweden); NIES (Japan); PIK (Germany); UN Population Division (UN, New York); UNU Maastricht (Netherlands); WBGU (Germany); Tufts University (US); Tyndall Centre (UK); Univ. Wisconsin (US); World Bank (Washington DC); Yale University (US).
External Contracts and Grants that Extend into 2011 And Beyond

TNT had external funding of Euro 61,453 in 2009 and Euro 73,039 in 2010.

In anticipation of the new 2011–2015 Research Plan and in order to allow the Institute maximum flexibility in devising its technology research program and strategy, the TNT Program has refrained from committing the Institute to externally funded research projects beyond 2010 (i.e. the completion of its current 5-year research cycle). The last remaining external contract EU-MONITOR will come to completion by May 2011. The ongoing collaboration with the German Advisory Committee on Global change (WBGU) which includes partial remuneration of TNT research time and travel expenses will continue in 2011.
Advanced Systems Analysis Program

The Advanced Systems Analysis (ASA) Program was formed via a merger of the current Dynamic Systems (DYN) Program and the Integrated Modeling Environment (IME) special project in 2011. The research program descriptions given below correspond to the current program figurations of DYN and IME.

ASA–Dynamic Systems (DYN)

Program Focus and Relevance

In ASA–DYN, the research goals will include synthesis of integrated knowledge from alternative models; identification of signals on critical changes; control of heterogeneous dynamical systems subject to endogenous and random exogenous constraints; analysis of interconnected dynamic games and formation of coalitions; and assessment and control of fragile dynamical networks. A strong applied focus is intended.

Core research topics will include: (i) integration of models of complex dynamic systems; (ii) management of heterogeneous processes; and (iii) game dynamics and robust decisions. In-house collaborative research topics will include: (i) systemic risk in network dynamics in collaboration with the Evolution and Ecology (EEP) Program; (ii) global economic growth with the World Population (POP) Program; (iii) attainability of low carbon economies with the Mitigation of Air Pollution and Greenhouse Gases (MAG) Program and the IME project; and (iv) integrated modeling of forest ecosystems with the Ecosystems Services and Management (Forestry) ESM–FOR Program and EEP.

ASA–DYN research will contribute to the cross-cutting research theme of Advanced Systems Analysis (ASA); the collaborative research effort in systemic risk and network dynamics will also contribute to ASA. Collaborative research on global economic growth will contribute to the area of Drivers of Global Transformation, and research on attainability of low carbon economies and collaborative research on integrated modeling of forest ecosystems will contribute to the Energy and Climate Change Area.

Building on Current Program Expertise and Past Achievements

In its work, ASA–DYN uses a broad range of instruments spanning control theory, probability theory and mathematical economics. The major achievements of recent years include: (i) creation of a new branch of control theory to deal with infinite-horizon processes of economic growth; (ii) application to generating long-term growth projections for selected economies; (iii) development of a new system-robust stabilization technique and demonstration of its applicability in a problem of stabilization of atmospheric greenhouse gases; (iv) development of a numerical technique for attainability analysis of a DICE-type global climate-economy model; (v) analysis of the co-evolution of a country’s GDP and transport infrastructure with application to selected EU countries; and (vi) analysis of equilibria in multi-agent dynamic games.
The ASA–DYN group will use its recent achievements and current strengths to contribute to the development of IIASA’s new cross-cutting research theme on Advanced Systems Analysis (ASA). ASA–DYN will adapt earlier developed approaches to new challenges and introduce methodological innovations. In research on Advances in Modeling Dynamic Systems, the goal will be to acquire an understanding of the role of heterogeneity in systems dynamics. Sustainable management of large-scale socioeconomic systems, their factorial and spatial diversification, and cross-dependency of their driving factors will constitute issues for research aimed, in particular, at contributing to the Drivers of Global Transformation area. The increasing interconnectivity of the key actors on the world scene—emergence and breaks down of coalitions, development and resolution of conflicts, changes in actors’ vital interests, etc.—will provide a basis for further advances in research on and policy applications of dynamic games. An innovative “model integration” methodology will be developed to generate integrated knowledge based on analysis of families of “partial” models describing the underlying complex systems from different perspectives. Research on Extreme Events, Systemic Risks, and Robust Solutions will concentrate on devising approaches to studying systemic risk in dynamic networks; the key challenges will be understanding generic mechanisms that enable local failures to propagate through the system, and identifying principles for failure-robust network designs. As part of the ASA Forum, DYN will contribute to exploration of innovations in Systems Analysis, and to development of IIASA’s “Dream Valley” artificial world—a test bed for the simulated interactions of economic, social, and environmental actors in the context of IIASA’s three global problem areas.

### Five Representative Recent Research Publications


### Two Representative Recent Policy Applications


### Human Resources (excluding guest scholars)

**Full Time**

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Field of expertise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arkady Kryazhimskiy</td>
<td>Program Leader</td>
<td>Dynamic games, optimal control</td>
</tr>
</tbody>
</table>
**Part Time**

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Field of expertise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sergey Aseev</td>
<td>Research Scholar</td>
<td>Dynamic systems, optimal control</td>
</tr>
<tr>
<td>Brian Fath</td>
<td>Research Scholar</td>
<td>Systems ecology, network analysis, modeling</td>
</tr>
<tr>
<td>Elena Rovenskaya</td>
<td>Research Scholar</td>
<td>Optimal control, ill-posed problems</td>
</tr>
<tr>
<td>Gerald Silverberg</td>
<td>Research Scholar</td>
<td>Economics, mathematical systems theory</td>
</tr>
<tr>
<td>Alexander Tarasyev</td>
<td>Research Scholar</td>
<td>Optimal control, differential games</td>
</tr>
<tr>
<td>Chihiro Watanabe</td>
<td>Research Scholar</td>
<td>Techno-economic systems, institutional innovation</td>
</tr>
</tbody>
</table>

**Key Collaborating Institutions**

Austrian Institute for Economic Research, Vienna, Austria; Bologna University, Italy; Bundeswehr University, München, Germany; Delhi Institute of Economic Growth, India; East Office of Finnish Industries, Finland; Geophysical Center, Moscow, Russia; Institute for Advanced Studies, Vienna, Austria; Institute of Mathematics and Mechanics, Ekaterinburg, Russia; International Federation for Automatic Control (IFAC), INSEAD Karlsruhe Institute of Technology, Germany; Kiel University, Germany; Kyoto Institute of Technology, Japan; Moscow State University, Russia; National Center for Physics, Islamabad, Pakistan; Steklov Mathematical Institute, Russia, St-Petersburg University, Russia; Swedish Agricultural University, Sweden; Tokyo Institute of Technology, Japan; University of Venice, Italy; University of Helsinki, Finland; University of Georgia, USA; University of Porto, Portugal; University of Southern Denmark, Denmark; University of Zurich, Switzerland; Vienna Technical University, Austria; Vladimir State University, Russia.

**External Contracts and Grants that Extend into 2011 And Beyond**

ASA–DYN had external funds in the amount of Euro 14,471 in 2009 and of Euro 14,000 in 2010. No external contracts and grants extend into 2011.

**ASA–Integrated Modeling Environment (IME)**

**Program Focus and Relevance**

The objective of the ASA–IME project within the new ASA Program is to develop new modeling methods and tools necessary for strengthening capabilities in modeling complex problems for which known methodology and/or general purpose modeling tools are inadequate.

IIASA aspires to be the world leader in system analysis to develop and apply analytical methods to find solutions to global problems. Models have been growing in complexity and size, and are often developed by integration of models and/or data developed by different teams; they also need to properly treat uncertainty, and risks, as well as multidimensional (social, economic, environmental, spatial and temporal) distributions. Moreover, the modeling processes supporting policy analysis must meet the requirements of credibility, transparency, replicability, interactivity with users and integration across models.
ASA–IME will contribute to ASA research by strengthening capabilities in Web-enabled structured modeling, multi-criteria analysis, robust decision making under uncertainties and stochastic optimization. New capabilities will be developed for Web-enabled collaborative modeling, infrastructure for an IIASA common research database, integrated problem analysis, solutions for security of interconnected anthropogenic and natural systems under endogenous uncertainty, problem-oriented data harmonization, and analysis of attainable goals for conflicting criteria.

Through a cluster of collaborative projects, ASA–IME will enable integration of these capabilities with methodologies developed by the collaborating programs, and apply them to specific research projects aiming at solution of complex problems. In this way ASA–IME will contribute to the Food and Water and to the Energy and Climate Change Areas.

**Building on Current Program Expertise and Past Achievements**

The ASA–IME strategic approach exploits the problem-oriented motivation for development of new methods and tools. This application orientation has been tested and proven true in new methods developed for application in collaboration with colleagues from several IIASA programs (MAG, ENE, ESM–FOR, ESM–LUC and RPV).

ASA–IME has developed expertise in large-scale models with complex structures, inherent uncertainty, integrated management of catastrophic risks, probabilistic downscaling, model-based decision-making support, multiple-criteria analysis, linear and non-linear optimization, integrated model analysis, modeling technology, collaborative modeling and Web-enabled applications based on relational databases. This summary is focused on recently developed capabilities and on outlining the new capabilities planned.

ASA–IME’s work in stochastic programming, non-smooth optimization, integrated risk management and fast adaptive Monte Carlo optimization methods have been expanded to non-Bayesian models with imprecise multi-dimensional, multi-modal probability distributions, probabilistic downscaling, heterogeneous extreme events, and multi-agent domains. It is planned to expand this expertise to develop new methods for designing solutions to achieve security of food, energy, water and environment in large-scale interconnected anthropogenic and natural systems. Resilience of such solutions will be achieved by incorporating anticipative and adaptive decisions within integrated multi-stage decision processes.

New data harmonization models and methods will be based on probabilistic and new stochastic robust down-/up-scaling methods and kernel smoothing procedures. Such type of kernels have been also used for designing robust solutions for catastrophe risk management, requiring catastrophe generators that are base on dedicated fast Monte Carlo simulations.

**Five Representative Recent Research Publications**


### Four Representative Recent Policy Applications

Makowski, M., Granat, J., Ren, H., Schenler, W., and Hirschberg, S. Requirement analysis and implementation of the multi-criteria analysis in the NEEDS project. Interim Report IR-09-09, IIASA, Laxenburg, Austria, 2009


### Human Resources (excluding guest scholars)

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Field of expertise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marek Makowski</td>
<td>Research Scholar</td>
<td>Operations research</td>
</tr>
<tr>
<td>Yuri Ermoliev</td>
<td>Institute Scholar</td>
<td>Mathematics</td>
</tr>
<tr>
<td>Hongtao Ren</td>
<td>Research Scholar</td>
<td>Knowledge sciences</td>
</tr>
</tbody>
</table>

### Representative Recent Collaborating Institutions

Only key institutions recently collaborating with ASA–IME are summarized. The list is grouped by countries listed in lexicographical order: Canada (Ottawa University); Germany (University of Federal Armed Forces, Munich); Japan (Japan Institute of Science and Technology; COE of Kyoto University); the Netherlands (World Food Studies Institute, Amsterdam); Norway (Throntheim and Bergen Universities, SINTEF); Poland (National Institute of Telecommunications; Warsaw University of Technology, Systems Research Institute); Sweden (Stockholm University); Switzerland (Paul Scherrer Institute, Villigen PSI); UK (University College, London); Ukraine (Institute of Economics and Forecasting, Kiev; Institute of Cybernetics, Kiev).

ASA–IME also coordinates two collaborative networks of leading experts in the fields of:
- Advanced methods and tools for complex system modeling; and
- Stochastic programming, modeling uncertainty and risk, spatial land use modeling.

These networks (each involving researchers from up to 20 institutes and universities) have been maintained for about two decades, and have resulted in many various activities, including publications, exchange visits and conferences.

**External Contracts and Grants that Extend into 2011 and beyond**

ASA-IME has external funding in the amount of Euro 54,668 in 2009 and Euro 4,402 in 2010.

A new project on Energy Efficiency and Risk Management in Public Buildings (EnRiMa) was recently funded in the amount of Euro 291,305. This project is to integrate interdisciplinary knowledge into a state-of-the-art decision-support system (DSS) for operators of energy-efficient buildings and spaces for public use. In this project, IIASA’s main responsibilities are: to design and implement the DSS architecture, the Web services linking distributed elements of the DSS, the data warehouse, and integrate them with the stochastic model and its solver into a dedicated Web-enabled DSS Engine, which in turn will be accessed by the GUI and automatic data collection system (to be developed by other EnRiMa partners) through dedicated Web services. Moreover, IIASA will assist in the symbolic model specification and in the selection of algorithms for solving the stochastic optimization, as well as in modeling of prices and loads, and handling uncertainties in energy flows. Thus, IIASA will lead the Work-Package 4, through which the decision-making core of the DSS EnRiMa will develop.

EnRiMa will provide substantial resources and incentives for strengthening IIASA capabilities in model-based decision-making support that requires modern methodology and technology for implementation of complex models: robust solutions for coping with inherent uncertainties, stochastic optimization, multi-criteria analysis, architecture of complex DSS, distributed Web-enabled interdisciplinary modeling, Web services, RDBMS-based structured modeling (that includes data warehouses). Thus the experience and software developed for EnRiMa will provide a solid basis for their generalization and adaptation to the needs of IIASA programs, collaborating institutions, and the capacity building activities (in a similar way to the past EU-NEEDS project).

The expected outcome of the project will also considerably contribute to cost-effective reduction of energy use and CO2 emissions without compromising comfort and risk tolerance beyond desired levels.
About IIASA

IIASA is an international, independent, and interdisciplinary research institution with nearly forty years’ experience in researching global change. IIASA is sponsored by its National Member Organizations (NMOs). In 2011 these were:

- **AUSTRIA** The Austrian Academy of Sciences
- **BRAZIL** Center for Strategic Studies and Management in Science, Technology and Innovation (CGEE)
- **CHINA** The National Natural Science Foundation of China
- **EGYPT** The Academy of Scientific Research and Technology (ASRT)
- **FINLAND** The Finnish Committee for IIASA
- **GERMANY** The Association for the Advancement of IIASA
- **INDIA** The Technology Information, Forecasting and Assessment Council (TIFAC)
- **MALAYSIA** Academy of Sciences Malaysia
- **JAPAN** The Japan Committee for IIASA
- **NETHERLANDS** The Netherlands Organization for Scientific Research (NWO)
- **NORWAY** The Research Council of Norway
- **PAKISTAN** The Pakistan Academy of Sciences
- **REPUBLIC OF KOREA** National Research Foundation of Korea (NRF)
- **RUSSIAN FEDERATION** The Russian Academy of Sciences
- **SOUTH AFRICA** The National Research Foundation
- **SWEDEN** The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (FORMAS)
- **UKRAINE** The Ukrainian Academy of Sciences
- **UNITED STATES OF AMERICA** The National Academy of Sciences