

SYSTEMS ANALYSIS 2015

A conference in celebration of Howard Raiffa

Conference Program, Information,
and Book of Abstracts

11–13 November 2015
IIASA, Laxenburg, Austria

CONFERENCE VERSION

Conference partners



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



*Institute for Operations Research
and the Management Sciences*

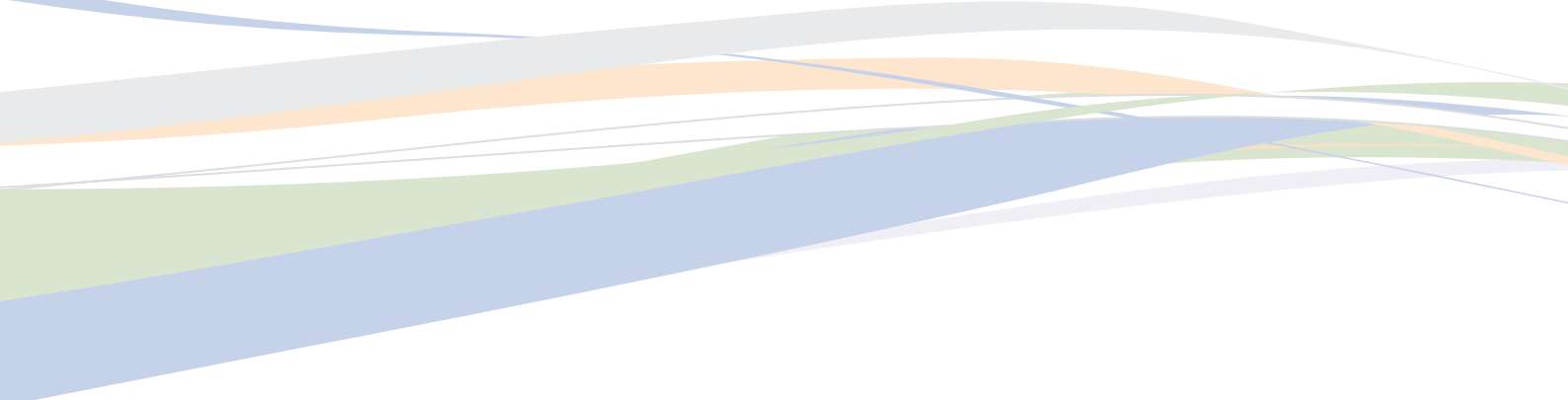


NANYANG
TECHNOLOGICAL
UNIVERSITY

Complexity Institute



SANTA FE
INSTITUTE



© International Institute for Applied Systems Analysis

Information in this publication is correct when going to print on 10 November 2015. Views or opinions expressed herein do not necessarily represent those of IIASA, its National Member Organizations, or the conference partner organizations.

Printed by IIASA on environmentally-certified paper

ISBN 978-3-7045-0152-3

Contents	1
Welcome	3
Conference at a Glance	4
11 November 2015	6
12 November 2015	8
13 November 2015	9
Dignitaries and Speakers	10
Posters	43
S1: Requirements for Methodological Advances in Systems Analysis	44
S2: Trans-disciplinary Inspiration in Systems Thinking	47
S3: The Art and Craft of Systems Analysis	53
S4: New Methods for Understanding Complex Systems	60
S5: Addressing Diversity in Social Systems	66
S6: Devising Integrated Solutions	73
General Information	82
Acknowledgments	83
Logistics	84
Evening Events	87
Map of Vienna	88
Map of Conference Center Laxenburg	89
Notes	90

A conference in celebration of Howard Raiffa



The Systems Analysis 2015 conference is dedicated to Howard Raiffa for his huge contribution to systems analysis. As an influential Bayesian decision theorist, Raiffa is a pioneer in the field of decision analysis, with works in statistical decision theory, game theory, behavioral decision theory, risk analysis, and negotiation analysis.

Raiffa played a key role in the international negotiations that established the International Institute for Applied Systems Analysis and subsequently became its first Director from 1972-1975. He is currently the Frank P. Ramsey Professor (Emeritus) of Managerial Economics, a joint chair held by the Business School and the Kennedy School of Government at Harvard University, USA.

Welcome to Systems Analysis 2015



I would like welcome you, as speakers and delegates from across the globe, to discuss the current state and future directions of systems analysis.

The significance of systems analysis is growing. Narrowly focused, single-disciplinary sciences alone cannot adequately identify smart pathways through the complexities of increasing globalization, shifts in economic and political power, taxing environmental challenges, and unpredictable social conflicts. A systems approach is required to reach a world that accommodates the needs and aspirations of different groups and respects the limits imposed by the planet itself. Systems analysis strives to develop integrated, interdisciplinary, multiscale approaches that consider social, economic, and environmental aspects, to look across borders and sectors in order to identify feedbacks, trade-offs, and synergies.

By hosting Systems Analysis 2015, IIASA, in partnership with the Santa Fe Institute, USA, the Complexity Institute at Nanyang Technological University, Singapore, and the Institute for Operations Research and Management Sciences, USA, aims to provide a platform:

- to appraise the state of the art of methods of systems analysis,
- to showcase recent methodological advances with high future potential,
- to identify gaps in current approaches that need to be overcome for meeting the new challenges, and
- to inspire transdisciplinary thinking and the transfer of methodological knowledge among different applications of systems analysis.

Over the course of three days, you will get the chance to meet other systems analysts from around the world, helping you to forge new, productive research collaborations that will bolster this field of research. IIASA will proactively facilitate the ongoing development of such networks and I will be delighted to hear about the outcomes of such fruitful collaborations in two years' time, at the next Systems Analysis conference.

A handwritten signature in blue ink, reading "Pavel Kabat". The signature is fluid and cursive, with a large loop at the beginning.

Professor Dr. Pavel Kabat
IIASA Director General and CEO

Conference at a Glance

11 NOVEMBER 2015

09:00–09:35	Opening Session: Welcome Addresses
09:35–10:45	Framing Session: Two Keynote Lectures
10:45–11:15	Coffee break
11:15–12:45	Session 1: Requirements for Methodological Advances in Systems Analysis
12:45–13:45	Lunch
13:45–15:45	Session 2: Trans-disciplinary Inspiration in Systems Thinking
15:45–16:15	Coffee break
16:15–17:45	Session 3: The Art and Craft of Systems Analysis (Part 1)
18:00–18:30	Music & Science: IIASA Goodwill Ambassador, Vienna Philharmonic
18:30–20:30	Poster Session and Reception

12 NOVEMBER 2015

09:00–11:00	Session 3: The Art and Craft of Systems Analysis (Part 2)
11:00–11:30	Coffee break
11:30–13:15	Howard Raiffa Session
13:15–14:15	Lunch
14:15–15:45	Session 4: New Methods for Understanding Complex Systems (Part 1)
15:45–16:15	Coffee break
16:15–18:15	Session 4: New Methods for Understanding Complex Systems (Part 2)
18:15–18:45	Coffee break
18:45–20:00	IIASA and Austrian Academy of Sciences Public Lecture featuring Robbert Dijkgraaf
20:00–21:00	Reception

13 NOVEMBER 2015

09:00–10:30	Session 5: Addressing Diversity in Social Systems (Part 1)
10:30–11:00	Coffee break
11:00–12:00	Session 5: Addressing Diversity in Social Systems (Part 2)
12:00–13:00	Lunch
13:00–14:30	Session 6: Devising Integrated Solutions (Part 1)
14:30–15:00	Coffee break
15:00–16:30	Session 6: Devising Integrated Solutions (Part 2)
16:30–17:00	Coffee break
17:00–19:00	Closing Session: A New Generation of Systems Analysis
19:00–22:00	Dinner at Heurigen in Klostergasthaus Thallern

Conference Program – Day 1

11 November 2015

OPENING SESSION

09:00–09:35

Conference participants are welcomed by representatives of all four conference partner institutions.

Pavel Kabat, IIASA Director General and CEO

Don Saari, IIASA Council Chair

Howard Raiffa (video message)

L. Robin Keller, INFORMS President

Peter M.A. Slood, NTU's Complexity Institute Director

Luís Bettencourt, Santa Fe Institute

Elena Rovenskaya & Ulf Dieckmann, Vice-chairs of the conference Scientific Committee

FRAMING SESSION: TWO KEYNOTE LECTURES

09:35–10:45

The framing session sets the stage for the conference. It reflects on the current revival of systems thinking; highlights the major new challenges for systems analysis that require methodological advances; showcases a recent application of systems analysis that has been enabled by methodological advances; and discusses the plurality of contemporary systems-analysis approaches among disciplines and along the traditional continuum between reductionism and holism.

Introduction & chair: Don Saari

Keynote Lectures:

Simon A. Levin: Current revival of systems thinking and major challenges for systems analysis

Nebojsa Nakicenovic: Recent applications of systems analysis for achieving sustainable futures for all on a safe planet

SESSION 1: REQUIREMENTS FOR METHODOLOGICAL ADVANCES IN SYSTEMS ANALYSIS

11:15–12:45

This session focuses on the methodological advances required for the successful future development of systems analysis as an approach to address the 21st century's major transformations. These advances need to expand the prowess of systems analysis in addressing challenging features of complex adaptive systems, such as nonlinearities and path dependence, surprises and tipping points, process uncertainty and model uncertainty, macroscopic patterns emerging from microscopic processes, massive availability of highly multivariate yet often unstructured and imprecise data, bounded rationality driving exchanges among social and economic actors, and impacts cascading across extended and interconnected networks.

Introduction & chair: Marten Scheffer

Jill Jäger: Methodological advances for transformative research

Beth Fulton: Linking scales & "I am not a modeller" – The biggest challenges in socioecological modelling

Wolfgang Lutz: What should be the sustainability criteria in systems models?

SESSION 2: TRANS-DISCIPLINARY INSPIRATION IN SYSTEMS THINKING

13:45–15:45

This session showcases the diversity of conceptual approaches that different fields of natural and social science have developed for defining and analyzing systems. Elucidating alternative systems perspectives across research areas as disparate as neuroscience, quantum theory, engineering sciences, ecology, economics, psychology, sociology, and computer science, key ideas concerning system elements, system interconnectedness, system boundaries, and system dynamics will be introduced and compared, with the goal of promoting trans-disciplinary inspiration in systems thinking.

Introduction & chair: Mark Stafford-Smith

Brian Fath: Sustainability of complex systems: Insights from ecological dynamics

Yamir Moreno: From small to big data: The physics of human behavior

Alexey Gvishiani: Systems analysis for geophysics: Challenges of the 21st century

Luciano Pietronero: New metrics for economic complexity: Measuring the intangible growth potential of countries

SESSION 3: THE ART AND CRAFT OF SYSTEMS ANALYSIS

16:15–17:45

Both art and craft are involved in all major steps of systems analysis – from posing a specific research question, to specifying the assumptions underlying a model, to transforming those assumptions into mathematical or computational form, and to representing and communicating the results. These features are making systems analysis an exciting and creative process.

This session considers the creative tensions inherent in this process by touching on the following questions: What modern approaches can be recommended for model selection, calibration, and validation? How are systems boundaries best to be defined, emergent phenomena tackled, robustness checks designed, and validity limits delineated? How can multiple models be compared, interfaced, and integrated? How can a proliferation of false positives be avoided as the pool of data that can be correlated explodes? How can big data be used while skirting a temptation to construct big models in which a plethora of nonlinear interactions defies understanding and associated uncertainties cannot be assessed? In any of these regards, are best-practice recommendations becoming available that help delineate a safe operating space for systems analysis?

Introduction & chair: Prabhat Ranjan

[Mark Beaumont](#): Approximate Bayesian computation: Methods and applications for complex systems

[Werner Römisch](#): Energy systems under uncertainty: Modeling and computations

[Petr Shebalin](#): Linking probabilistic and deterministic forecast methods: Systems analysis for predicting earthquakes

MUSIC AND SCIENCE

18:00–18:30

Introduction: Pavel Kabat

Concert by members of the Vienna Philharmonic Orchestra, IIASA Goodwill Ambassador

POSTER SESSION

18:30–20:30

The dedicated poster session will enable conference participants to scope and share a diversity of perspectives on innovative methodologies, applications, and future challenges of systems analysis. To facilitate exchanges, all poster presenters are kindly asked to be with their posters throughout this session.

Conference Program – Day 2

12 November 2015

SESSION 3: THE ART AND CRAFT OF SYSTEMS ANALYSIS (continued)

09:00–11:00

Introduction & chair: Prabhat Ranjan

Marten Scheffer: Foreseeing critical transitions

Ronald R. Yager: Fuzzy sets methods for constructing multi-criteria decision functions: Mixing words and mathematics

Andrzej Ruszczyński: Risk quantification and control: Challenges and opportunities

Yoshihide Wada: Reducing water scarcity possible by 2050: Linking global assessments to policy dimensions

HOWARD RAIFFA SESSION

11:30–13:15

This special session is dedicated to Howard Raiffa's work and vision for the future of systems analysis. Speakers will commemorate his pioneering contributions to the field by showing how these are influencing contemporary research and practice.

Introduction & chair: Detlof von Winterfeldt

David E. Bell: Policy, probability and preference

Ali E. Abbas: The need for a sound decision-making system in systems analysis

Raimo P. Hämäläinen: Behavioural aspects of decision analysis

Ralph L. Keeney: Constructing value models for applied systems analysis

SESSION 4: NEW METHODS FOR UNDERSTANDING COMPLEX SYSTEMS

14:15–18:15

As the challenges of systems analysis develop, so must its methods. The system analyst's tool chest can be expanded in three ways: by taking advantage of as yet untapped advances in mathematics and computer science, by the gradual honing of tools applied and developed in a disciplinary context, and by trans-disciplinary innovation and cross-fertilization.

This session will provide an extensive horizon scan of new methods and approaches that have potential for strengthening systems analysis in the 21st century.

Introduction & chairs: Ulf Dieckmann & Elena Rovenskaya

Luís Bettencourt: The city as a system

Dirk Helbing: From computational social science to global systems science

Siew Ann Cheong: Critical transitions in markets and societies

Stefan Thurner: Management of systemic risk

Soo Hong Chew: Familiarity bias breeds investment if you have the right gene

Boris Mirkin: Data summarization at clustering and ranking

Mauro Martino: Data visualization and artificial intelligence: The real time exploration of unstructured big data

PUBLIC LECTURE: BUILDING BRIDGES BETWEEN SCIENCE AND POLICY

18:45–20:00

Public lecture jointly organized by IIASA and the Austrian Academy of Sciences (ÖAW), and followed by a reception.

Introduction & chair: Pavel Kabat

Welcome: Anton Zeilinger, President, Austrian Academy of Sciences

Public lecture: Robbert Dijkgraaf, Director, Institute for Advanced Study in Princeton: Building bridges between science and policy

SESSION 5: ADDRESSING DIVERSITY IN SOCIAL SYSTEMS

09:00–12:00

Scientific insights into global transformations invariably require accounting for a plurality of stakeholder groups and interests. Contemporary applications of systems analysis are breaking new ground by explicitly accounting for such diversity, as well as for the associated complexity of human behavior. Participatory processes engaging stakeholders and policy makers in the whole cycle of designing and implementing research have proven invaluable for promoting a wider acceptance of scientific analyses. The interfacing of science with art is also increasingly recognized as a powerful conduit for reaching broader audiences.

This session focuses on methodological approaches that facilitate stakeholder involvement and promote accounting for stakeholder diversity.

Introduction & chair: Mary Scholes

[Sergio Rinaldi](#): Modeling love dynamics

[L. Robin Keller](#): Multi-objective multi-stakeholder decision analysis

[Karl Sigmund](#): A new decision science for complex systems: A decade of enabling tool

[Christoph Hauert](#): Honour, shame and climate change – Lessons from public goods experiments

[Anna Scolobig](#): From stakeholder views to policy options

SESSION 6: DEVISING INTEGRATED SOLUTIONS

13:00–16:30

Systems-based models have been used to analyze and compare alternative policy options at various levels of governance. Governmental and international organizations have been customers of these analyses. This session addresses the science-for-policy topic from both perspectives and reflects on best practices for successfully structuring the communication between scientists, decision-makers, and the public.

Introduction & chair: Ali E. Abbas

[Robert Lempert](#): A new decision science for complex systems: A decade of enabling tools

[Xijin Tang](#): Perceiving societal risk from online community concern

[David McCollum](#): Harnessing systems analytical tools to develop sustainable energy scenarios for the 21st century

Panel 1: Science-policy interface in regard to air-quality and climate negotiations in Europe

[Markus Amann](#)

[Martin Williams](#)

Panel 2: Mobilizing mass action through mobile devices: Challenges and opportunities for science, policy, and governance

[Paul Chatterton](#)

[Linda See](#)

CLOSING SESSION: A NEW GENERATION OF SYSTEMS ANALYSIS

17:00–19:00

The closing session begins with poster awards with the three winners giving a five minute presentation on their poster. This will be followed by the Vice-chairs of the conference's Scientific Committee providing a synthesis of the conference and sharing their views on future directions for systems analysis. The session will close with a panel discussion followed by questions and answers with the audience.

Introduction & chair: Pavel Kabat

Poster awards voted for by conference participants (best poster by an early-career scientist, best poster by a mid-career scientist, best poster overall)

Award for most popular tweet of a quote from the conference.

[Ulf Dieckmann](#) & [Elena Rovenskaya](#): Conference synthesis and outlook for systems analysis

Panel: Outlook for systems analysis: [Luís Bettencourt](#), [Nadya Komendantova](#), [Martin Lees](#), [Raya Muttarak](#), [Stephen M. Robinson](#), [Don Saari](#), [Peter M. A. Sloot](#)

[Pavel Kabat](#): Closing remarks



ALI E. ABBAS

Ali E. Abbas is a professor of industrial and systems engineering and of public policy at the University of Southern California, USA. He received his higher degrees from the school of engineering at Stanford University, USA. Abbas has an MS in electrical engineering and one in engineering economic systems & operations research as well as two PhDs: one in management science and engineering, and a PhD minor in electrical engineering. His research interests include all aspects of decision making under broadly defined uncertainty. He is coauthor of "Foundations of Decision Analysis" with Ronald A. Howard, and the forthcoming book "Foundations of Multiattribute Utility". He serves as associate editor for both the *Operations Research* and *Decision Analysis* journals of Institute for Operations Research and the Management Sciences (INFORMS) and is the decision analysis area editor for the journal *IIE Transactions*. He has been presented with multiple research awards from the National Science Foundation including the National Science Foundation CAREER Award, and the inaugural class of the National Science Foundation I-Corps award. Abbas has organized numerous workshops including the decision analysis tracks of INFORMS 2007, 2008, the Bayesian inference and Maximum Entropy conference in 2005, and numerous workshops with NASA, the Transportation Security Administration, and other organizations.

The need for a sound decision-making system in systems analysis

Some of the significant features of our era include the design of large-scale systems; advances in artificial intelligence, medicine and public policy; the role of social networks in predicting behavior and toppling governments. A common theme in all these features is the need for a sound decision-making system. Some of the commonly cited obstacles for the use of decision analysis in large scale systems are the complexity of the analysis and the presence of multiple stakeholders with multiple objectives. The first part of this talk will discuss examples of some widely used (and flawed) decision-making methods that are still in use today, and the consequences of implementing them in large scale systems. The second part of the talk will discuss an application of decision analysis to an asteroid recovery mission and to the control of unmanned aerial systems.

- Howard Raiffa Session, Day 2
- Devising Integrated Solutions (Introduction & chair), Day 3



MARKUS AMANN

Dr. Markus Amann is Program Director of IIASA's Mitigation of Air Pollution & Greenhouse Gases (MAG) Program. He also serves as the head of the Centre for Integrated Assessment Modelling (CIAM) of the European Monitoring and Evaluation Programme (EMEP) under the Convention on Long Range Transboundary Air Pollution (CLRTAP).

Amann has been appointed as a member of the Clean Air Commission of the Austrian Academy of Sciences. He is a member of the Editorial Board of "Environmental Modelling and Software" and lead author for the Working Group III report of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).

Amann was a member of the Environmental Assessment Group of EUROTRAC-II, member of the Management Committee of Topic Centre for Air and Climate Change of the European Environment Agency (EEA), member of the Scientific Oversight Committee of the APHENA "Air Pollution and Health, A European and North American Approach" project of the Health Effects Institute (HEI, Boston, USA), reviewer for the AFO2000 German Atmospheric Research program and reviewer for the United States Acid Deposition Research Program NAPAP.

Science-policy interface in regard to air-quality and climate negotiations in Europe

■ Devising Integrated Solutions, Day 3



MARK BEAUMONT

Mark Beaumont is a professor of biostatistics at the University of Bristol. He holds a PhD in Genetics from the University of Nottingham, and also has been in receipt of a Wellcome Trust Mathematical Biology Fellowship, and an NERC Advanced Fellowship. He is primarily interested in population genetic modelling and analysis. Motivated by the challenges posed by population genetic data he has played a role in the development of several approaches for Bayesian inference in high-dimensional models, including approximate Bayesian computation (ABC) and pseudo-marginal MCMC. The main application of these methods in population genetics has been to infer demographic history using DNA sequence data, and also to detect the effects of selection in the genome. He has more recently become interested in applying ABC methods for parameter inference in agent-based models.

Approximate Bayesian computation: Methods and applications for complex systems

Approximate Bayesian computation (ABC) is a method for sampling parameter values from posterior distributions when the likelihood function is unavailable or difficult to compute. The key idea is to project the potentially high dimensional data onto a lower dimensional summary and then use Monte Carlo rejection algorithms based on the distance between simulated and observed summaries. It has been a popular approach in population genetics, but in the last five years has become more widely applied, for example, in epidemiological models, population dynamics, and systems biology, as well as in astronomy and climate modelling.

I will outline the main implementation issues in ABC, and the most promising approaches that have been taken to address them. I will review examples from a variety of systems in genetics and ecology. Possibly the most problematic issue in ABC, particularly for complex systems, arises from the difficulty in constructing models that can approximate the observations well. I will illustrate this with an example from recent joint work on an agent-based model for earthworm population dynamics. ABC has been used for some 'big data' problems, such as whole-genome inference in population genetics, and a major current focus of research is to extend this further. One very promising avenue of research is in the use of Expectation Propagation with ABC, and some recent studies are reviewed.

■ The Art and Craft of Systems Analysis, Day 1



DAVID E. BELL

David E. Bell is the George M. Moffett professor of agriculture and business at Harvard Business School. He teaches the MBA course in Agribusiness and also runs the annual Agribusiness Seminar that attracts 200 leading food executives each January to the HBS campus, and each year to one other location around the globe. He studies all aspects of the food chain, from farming to distribution to trends in consumer eating habits.

During 35 years on the HBS faculty David has taught a variety of courses to both MBAs and executives, including marketing, retailing, risk management and economics. Most recently he has taught the MBA Leadership and Corporate Accountability course. He has held a number of administrative positions at HBS including a previous term as chairman of the school's marketing faculty (2002-8) and senior associate dean for Planning and Recruiting (2008-12).

Policy, probability, and preference

Howard Raiffa's influential book "Decision Analysis" introduced a generation to problem structuring in the form of decision trees. Decision trees have three major components; alternatives, uncertainties, and values.

In the nearly 50 years that has passed since the book was published, the increasing availability of data and computing power has allowed science, systems analysis, to make ever more powerful forecasts of what will happen under different policies.

Models can be convincing in answering the if ... then part of a problem – assessing the probabilities associated with alternatives. If we reduce CO₂ emissions by half what does that do to sea levels in 2080? That's very useful if the policymaker sees sea level as the key issue. But decisions almost always involve trade-offs among multiple criteria. We argue that understanding the values of affected parties, and the concerns of key decision makers, is just as important to influencing policy as is forecasting. The talk will suggest a way forward.

■ Howard Raiffa Session, Day 2



LUÍS M.A. BETTENCOURT

Luís M. A. Bettencourt is a professor of complex systems at the Santa Fe Institute. He trained as a theoretical physicist and obtained his PhD at Imperial College London, UK in 1996, for research into statistical and high-energy physics models of the early universe. He has held postdoctoral positions at the University of Heidelberg, Germany, Los Alamos National Laboratory, USA, and at MIT—the Massachusetts Institute of Technology—in the Center for Theoretical Physics, USA.

He has worked extensively on cities and urbanization. His research emphasizes the creation of new, interdisciplinary syntheses to describe cities in quantitative and predictive ways, informed by the growing availability of empirical data worldwide. His research interests also include the modeling of innovation and sustainability in developing human societies, the dynamics of infectious diseases, and aspects of general information processing in complex systems. He is particularly interested in the interplay between information, structure, and scale in setting the properties of diverse complex systems.

The city as a system

Cities were among the earliest applications of concepts of systems dynamics and of integrated analysis methods. Early studies and applications generated enormous enthusiasm and suggested novel solutions that identified sector interdependencies and the importance of feedback processes. However, in retrospect, these initial approaches remained too close to engineering to be able to tackle the main social and economic drivers of urban societies. In my presentation, I will discuss how a convergence of ideas and data from across a number of disciplines is creating a new and deeper scientific view of cities and urbanizing societies. This includes a deeper understanding of urban economies; of processes of human development and economic growth; and of the quantity and role of infrastructure and resources in supporting spatially concentrated socioeconomic dynamics. I will show how the general properties of cities can be measured across different nations with distinct levels of socioeconomic development, and how such properties can be predicted using new models of socioeconomic networks of learning agents, embedded in a space that is self-consistently constructed. This shows that socioeconomic mechanisms of collective learning and action are the essence of cities, and demonstrates how urban space, infrastructure, and services must obey certain quantitative properties. This integrated understanding of cities also helps us generate more realistic

scenarios for sustainable development in a world that is increasingly urban.

- Opening Session: Welcome, Day 1
- New Methods for Understanding Complex Systems, Day 2
- Closing Session: (Panel member), Day 3



PAUL CHATTERTON

Paul is an accomplished environmental manager specialising in large scale solutions for low carbon development and sustainability.

As Director for REDD+ Landscapes with WWF, Paul has designed and initiated REDD+ programs at scale in the Amazon, Borneo, and Congo, has led strategic planning globally and is responsible for aligned implementation on forest and climate landscapes across the WWF network.

Paul has previously managed WWF's international efforts in Austria, the Pacific, and Papua New Guinea and before this ran his own company consulting on sustainable development and stakeholder participation in the Asia Pacific region.

Mobilizing mass action through mobile devices: Challenges and opportunities for science, policy, and governance

Citizen science and crowdsourcing have become increasingly popular ways of involving citizens in scientific research and for carrying out a variety of micro-tasks. There are many examples of successful citizen science projects and crowdsourcing platforms including the LandMapp project for community-based land tenure mapping; Moabi, which allows citizens to report illegal logging in the Congo jungles, both of which have been supported by IIASA and WWF (World Wide Fund for Nature); and Geo-Wiki, a tool for visualization, crowdsourcing and validation of global land cover, developed at IIASA. This talk will provide a brief overview of citizen science and crowdsourcing followed by the main achievements and lessons learned from the LandMap, Moabi, and Geo-Wiki projects. A number of challenges remain, such as how to move citizen participation from data collection to environmental stewardship, and how to scale up these efforts to tap into the large citizen networks and initiatives that are currently ongoing, e.g. WWF's Earth hour, which reaches a billion people. We will discuss these and other challenges in light of new opportunities in climate funding and other new sources of private funding, e.g. for green businesses.

- Devising Integrated Solutions, Day 3



CHEONG SIEW ANN

Siew Ann Cheong obtained his BSc (Hons) in physics from the National University of Singapore in 1997 and his PhD in theoretical condensed matter physics from Cornell University in 2006. He then spent a year and a half as a postdoctoral associate with the Cornell Theory Center, working on biological sequence segmentation, before joining the Nanyang Technological University as an Assistant Professor in Physics and Applied Physics in August 2007. His research interest is in understanding dynamics and organization of complex systems such as biological macromolecules, the brain, earthquakes, financial markets, and infectious diseases, through the analysis of high-frequency, large-volume time series data, as well as the development and analysis of toy models.

Critical transitions in markets and societies

Authors: James Peng Lung TAN^{1,3} Boon Kin TEH^{2,3} Darrell Jiajie TAY^{2,3} Teck Liang TAN^{2,3} and Siew Ann CHEONG^{2,3}

¹Interdisciplinary Graduate School, Nanyang Technological University, Singapore ²Division of Physics and Applied Physics, School of Physical and Mathematical Sciences, Nanyang Technological University ³Complexity Institute, Nanyang Technological University

Complex systems can frequently be found in multiple stable states. Characterizing the dynamics within such stable states, and the critical transitions between them remain an important challenge in our quest to understanding complex systems. In the first part of this talk, I will describe how we detected early warning signatures of critical transitions in housing markets. By examining the power spectrum, autocorrelation, and variance of monthly data in the US and Singapore housing markets, we found signs of critical slowing down preceding several transitions. For the Singapore housing market, we also identify new launches as perturbations to the system, to find slower and slower recovery rates that suggest that we are approaching a critical transition. In the second part of my talk, I will describe how the perturbation idea can be applied to the analysis of sociopolitical regime shifts. In online discussion forums, threads can be thought of as perturbations to the prevailing mood, which relaxes in the form of an exponentially decaying number of posts to these threads. Though these decay rates do not vanish, we saw strong signs of critical slowing down preceding the 2011 Singapore General Election in three highly political discussion forums. We then show how we can mine the contents of these discussions to extract an effective order parameter for the critical transition. In the final part of my talk, I will describe how the dynamics of cross correlations in the stock market can be visualized in the form of fusion-fission diagrams, how these relates to the 'soup-of-groups' model, and how we can derive a mean-field theory from the model to perform quantitative forecasting.

■ New Methods for Understanding Complex Systems, Day 2



SOO HONG CHEW

Chew Soo Hong is professor at the National University of Singapore (NUS) and adjunct professor at the Hong Kong University of Science and Technology (HKUST). Chew received his Ph.D. in interdisciplinary studies from the University of British Columbia and has previously taught at the University of California, Irvine, Johns Hopkins University, and University of Arizona. He is among the pioneers in axiomatic non-expected utility models and is a fellow of the Econometric Society which awarded him the Leonard J. Savage thesis prize. Chew has directed HKUST's center for Experimental Business Research, inaugurated by Vernon Smith in 1998, and is co-director of NUS' lab for Behavioral x Biological Economics and the Social Sciences which aims to bring together genomics, neuroscience, decision theory, and behavioural and experimental economics to seek a deeper understanding of decision making at the neural and molecular levels. Chew has published in well regarded journals such as *Econometrica*, *Journal of Economic Theory*, and *Review of Economic Studies* as well as more biology oriented ones including *PRSB*, *Neuron*, and *PLoS ONE*.

Familiarity bias breeds investment if you have the right gene

In two important works (Feldstein and Horioka, 1980; French and Poterba, 1991), it has been found that investors focus their portfolios disproportionately on domestic equities contravening lessons from advances in financial economics over the past decades. This is corroborated subsequently in the works of Huberman (2001) and Coval and Moskowitz (2002) which provide evidence of a domestic home market bias favoring shares in

companies that are geographically proximate. We will discuss findings from experimental studies using molecular genetics and neuroimaging to establish a link between the GABAergic system (linked to tranquilizer drugs such as Valium and Xanax) and familiarity bias through the amygdala known for its role in emotion regulation in relation to anxiety and depression.

■ New Methods for Understanding Complex Systems, Day 2



ULF DIECKMANN

Dr. Ulf Dieckmann is Program Director of IIASA's Evolution and Ecology Program (EEP). He works on the theory of adaptive dynamics, fisheries-induced evolution, cooperation evolution, speciation theory, spatial ecology, life-history theory, and on problems in theoretical evolutionary ecology.

Dieckmann received his bachelor's degree in physics and his master's degree in theoretical physics from the University of Aachen, Germany. He completed his PhD research on theoretical biology at Leiden University, the Netherlands, and obtained his Habilitation (*venia legendi*) in biomathematics from the University of Vienna. He has worked at Stanford University and the Xerox Palo Alto Research Center, USA, the Research Center Jülich, Germany, the University of York, UK, Leiden University, the Netherlands, and the University of Vienna, Austria. He has been a visiting professor at the University of Montpellier, France, and a research fellow at the Institute for Advanced Study, Wissenschaftskolleg zu Berlin, Germany.

■ Opening Session: Welcome, Day 1

■ New Methods for Understanding Complex Systems (Introduction & chair), Day 2

■ Closing Session: Conference Synthesis and Outlook for Systems Analysis, Day 3



ROBBERT DIJKGRAAF

Robbert Dijkgraaf is director and Leon Levy professor of the Institute for Advanced Study in Princeton, USA, one of the world's leading centers for theoretical research and intellectual inquiry. Past faculty have included distinguished scientists and scholars such as Albert Einstein, Robert Oppenheimer, John von Neumann, Kurt Gödel, and George Kennan.

Dijkgraaf, a mathematical physicist, has made important contributions to quantum field theory, string theory, and black holes, as well as pure mathematics. Past president of the Royal Netherlands Academy of Arts and Sciences and current president of the InterAcademy Partnership, the global network of more than 130 national academies of science, medicine, and engineering, Dijkgraaf is a distinguished public policy adviser and passionate advocate for science, education, and the arts.

Building bridges between science and policy

The global interactions of science and policy are caught in a web of great complexity. We are living in times of unprecedented levels of scientific knowledge and understanding. Yet, the climate in which to integrate science to policy is becoming very harsh, with stormy winds of public opinion and partisan politics. Many national and intergovernmental organizations lack the strength and resources to withstand these forces.

Underlying all this is the paradox of scientific progress. While research digs into deeper layers of understanding, it creates more distance between the scientific community and the general public. On the other hand this knowledge becomes more and more relevant to our daily lives. In the end science can seem to be both infinitely far away and at the same time infinitesimally close by.

In providing the best advice to national governments and intergovernmental organizations scientists have to close this gap with the public. In doing so, they have to navigate between two hazards: the trap of a too-activist role, and the irrelevance and isolation of an ivory-tower mindset.

They also have to do this in a coordinated international effort. Science is increasingly a global effort, as are many of the challenges confronting our world such as energy, climate, water, health, food, and the environment.

There is a tremendous need to build sustainable bridges between science and policy, and provide objective, authoritative, credible, independent, and peer-reviewed advice based on the best global expertise.

■ Public Lecture, jointly organized by IIASA and the Austrian Academy of Sciences (ÖAW), Day 2



BRIAN D. FATH

Brian D. Fath is a professor in the Department of Biological Sciences at Towson University, USA, where he teaches courses in ecosystem ecology, environmental biology, networks, and human ecology and sustainability. He has also travelled internationally to teach courses on ecological networks and modeling worldwide.

Fath is also a researcher in the Advanced Systems Analysis Program at IIASA and scientific coordinator of the institute's Young Scientists Summer Program. He has published over 130 research papers, reports, and book chapters, and coauthored the books "Flourishing within Limits to Growth: Following Nature's Way", "A New Ecology: Systems Perspective Ecological Modelling", and the "Encyclopedia of Ecology."

He currently serves as editor-in-chief for the journal *Ecological Modelling* and is president of the North American Chapter of the International Society for Ecological Modelling. In 2012 he held a Fulbright distinguished chair position at the Parthenope University of Naples, Italy.

Sustainability of complex systems: Insights from ecological dynamics

Sustainability is an important concept, currently at the forefront of many policy agendas. Yet, the science of sustainability is still inchoate: What does it mean for a system to be sustainable? What are the features of sustainable systems and how can they be quantified? Systems ecology is built on Bertalanffy's premise that organisms, like all complex adaptive systems, are self-organized and interactive. This shifted our perspective from a linear mechanism to models that required a broader, holistic orientation in order to understand fully the dynamics involved. These complex systems operate by maintaining functional gradients away from equilibrium. While there are basic requirements regarding availability of input and output boundary flows and sinks, sustainability is centrally a feature of system configuration. A system must provide a basis of positionally balancing, wholeness-enhancing centers of activity. In this presentation, I provide an overview of concepts and methods developed in ecosystem theory to describe the structure and function of these self-sustaining autocatalytic configurations, and extend the methods to applications in economic and socio-economic systems.

■ Trans-disciplinary Inspiration in Systems Thinking, Day 1



ELIZABETH (BETH) FULTON

Dr. Beth Fulton is a principal research scientist with the Oceans and Atmosphere Flagship of the Commonwealth Scientific and Industrial Research Organisation (CSIRO), where she heads up the ecosystem modeling team. Fulton is also a member of the Centre of Marine Socioecology, a collaboration between the University of Tasmania, Australia; CSIRO; and the Australian Antarctic Division. Fulton has been with the CSIRO for the past 13 years, where she has developed various system modelling tools for studying marine ecosystems and sustainability. The best known tool is the Atlantis modeling framework, which has been applied to more than 30 marine ecosystems around the world. The models developed by Fulton's team are some of the first to give equal attention to the biophysical and human components of marine and coastal ecosystems. They underpin CSIRO's research into sustainably managing the potentially competing uses of marine environments and adaptation to global change, and have been used to consider effective ways of conserving and monitoring marine ecosystems.

Linking scales and "I am not a modeller" – The biggest challenges in socioecological modelling

Marine socioecological modeling (or "end-to-end modeling" as system approaches are often known in the marine world) is well past its infancy. It is sufficiently established now to have gone through cycles of application, uptake, and review of success. There have been successes, and it has supported more holistic management efforts, such as the restructuring of Australia's federal fisheries in 2005. However, major impediments remain in applying it at the scales necessary to cope with the cumulative pressures on marine and coastal systems. Scale is a problem; scientifically it is not a trivial task to deal with the processes that influence how marine and coastal systems function and respond across 14 orders of magnitude in space and time. However, the biggest challenge remains the broad societal reticence to engage with models and systems thinking, which is perceived, erroneously, as "beyond the average mind" or "too complex to be trustworthy." Whether through improved communication, capacity development, or technological advances, the barrier to uptake needs to be breached if the benefits of a systems approach are to be brought successfully to bear on the many pressures associated with global change.

■ Requirements for Methodological Advances in Systems Analysis, Day 1



ALEXEI GVISHIANI

Professor Alexei Gvishiani is Academician of the Russian Academy of Sciences (RAS), Doctor of Science in Physics and Mathematics, Director of the Geophysical Center RAS, Chairman of the National Geophysical Committee RAS, Deputy Academician-Secretary of the Earth Science Branch of RAS, and member of the Council of Federal Agency of Scientific organization of Russia. His areas of scientific research include mathematical methods of artificial intelligence and their application to geophysics, study of the Earth's magnetic field, geoinformatics, and systems analysis of seismic zonation. Gvishiani is the author of more than 273 scientific articles published in international and Russian scientific journals, including five monographs and five certificates of authorship. He is a foreign member of the Ukrainian Academy of Sciences and Romanian Academy of Technical Sciences, Honorary Doctor of the National Technological University of Ukraine, Professor of Lomonosov Moscow State University, and the Institute of Physics of the Earth, Paris. He has held high-level international positions of Vice-President of the Committee on Data for Science and Technology (CODATA), Vice-chair of the WDC Panel of International Council for Science (ICSU), and Vice-President of European Mediterranean seismological center (EMSC/CSEM, France). Currently, he is vice-chair and the Council member for Russia of the

governing Council of IIASA. He is also RAS delegate to the International Union of Geodesy and Geophysics (ICSU) and the Committee on Data of ICSU (CODATA). He was awarded the Order of Friendship of Russian Federation for his outstanding work in international scientific collaboration.

Systems analysis for geophysics: Challenges of the 21st century

Theoretical and applied studies in evaluation, prediction, and prevention of natural disasters, along with research in diminution of their vulnerability, are the major focus for systems analysis. Earthquakes, volcanic eruptions, tsunamis, hurricanes, floods, magnetic storms etc., being complex natural systems by themselves, are immersed into even more complex systems of permanently developed industrial, economic, demographic, scientific, and political environments.

Complexity of this system of systems exponentially grows with time. Adequate mathematical description and systems analysis of the multi-lateral interactions of these complex systems will require in the 21st century new mathematical approaches. The latter should come up with joint analysis of huge data flows of principally different origins that also increase with time.

After being tested and evaluated in numerous significant applied system analysis problems, such new mathematical techniques can be further developed theoretically into a new mathematical discipline. This will distinguish systems analysis of the 21st century from its forerunner. The new mathematical discipline may have its own axiomatics.

The methodology of the present systems analysis is mostly based on classical mathematical tools, created independently of the systems research. Advanced systems analysis in the 21st century will create its own methodological mathematical base, specially developed to serve practical (applied) system analysis. This will be an important step to understanding what the subject of the system analysis is.

■ Trans-disciplinary Inspiration in Systems Thinking, Day 1



RAIMO P. HÄMÄLÄINEN

Professor Raimo P. Hämmäläinen is the director and founder of the Systems Analysis Laboratory in Aalto University, Finland. He earned his MSc and PhD degrees in engineering mathematics and systems theory in 1972 and 1977 from the Helsinki University of Technology (now Aalto University). He is the author of over 200 publications on decision analysis; game theory; energy policy and environmental decision making; systems intelligence; and biological systems. He is also the designer of a number of well-known decision-analysis software programs including the web-HIPRE which is used worldwide in universities and research institutions. As a consultant he has helped to solve problems in the areas of environmental policy and risk analysis. He is a pioneer in the emerging field of behavioral operations research, which has attracted very strong interest in the operational research community. Hämmäläinen was nominated to be the Honorary President of the Finnish Operational Research Society for his contributions in developing this field in Finland. He was also a recipient of the MCDM Edgeworth-Pareto Award awarded by the International Society on Multiple Criteria Decision Making.

Behavioural aspects of decision analysis

Behavioral issues are always present when using modeling to support human problem solving and decision making. Behavioral effects can relate to the group interaction and communication, as well as to the possibility of procedural mistakes, cognitive biases and even to motivational issues. Decision analysis considers human behavior directly by

modeling preferences and risk attitudes. There is also extensive literature on the biases that we can observe in human decision making. Yet, we still have important research challenges in learning how to take decision analysis into practice while incorporating behavioral aspects. This challenge was identified early by the pioneer of decision analysis, Professor Howard Raiffa.

In this talk I will review recent advances in addressing behavioral aspects in decision analysis, negotiations, and in the process of systems-analytical problem solving in general. This theme is in the core of the emerging research area of behavioral operational research. Some cognitive biases can be mitigated but some are very persistent. Debiasing approaches are discussed and the emergence of the phenomenon of path dependence is demonstrated with the Even Swaps method, codeveloped by Howard Raiffa. Today, we need to pay increasing attention to behavioral aspects related to decision models, as they are being used extensively to tackle important problems like climate change.

■ Howard Raiffa Session, Day 2



CHRISTOPH HAUERT

Christoph Hauert is an associate professor in the Mathematics Department of the University of British Columbia, Canada. Previously he has worked in the University's Zoology Department and collaborated with Martin Nowak in the Program for Evolutionary Dynamics at Harvard University; among other positions. His primary research interest lies in the evolution of cooperation and the role of population structures.

Honour, shame and climate change – Lessons from public goods experiments

In view of dwindling global resources, increased pressures on social welfare states, and the threat of climate change, the sustainable management of public goods presents formidable challenges to human societies. In two behavioral experiments on public goods interactions and the closely related collective risk dilemma, individuals are asked to contribute funds to a common pool, which benefits everyone and hence generates a social dilemma where rational individuals attempt to free-ride on benefits generated by others—to the detriment of all. Public goods experiments show that revealing the identities of individuals who contributed least (shame), or contributed most (honor), both result in a significant increase of cooperation. This reflects practices that, for example, mandate restaurants to display health inspection results, or maintain public lists of the top tax delinquents. In the context of climate change, cooperation is significantly harder because the problem is global, participation is mandatory, and resources as well as risks are highly unevenly distributed. Possibly worst of all, the benefits of not contributing are immediate, whereas the rewards for successfully mitigating climate change are delayed by decades. Future rewards are discounted due to the risk that rewards may not get realized or the beneficiary may not live to enjoy them. In collective risk experiments participants were tasked to raise a target amount to avert “dangerous climate change.” Any leftover funds were theirs to keep (i.e., there were immediate benefits for shirking) and if the group achieved the target, additional benefits were paid out either the next day, seven weeks later, or, invested into planting oak trees. Comparing inter- and intra-generational discounting reveals a sobering trend: the longer the delay, the fewer groups reach the target. Our experiments confirm that negotiations to mitigate climate change are unlikely to succeed if individual countries’ short-term gains can arise only from defection.

■ Addressing Diversity in Social Systems, Day 3



DIRK HELBING

Dirk Helbing is professor of computational social science at the Department of Humanities, Social and Political Sciences and affiliate of the Computer Science Department at ETH Zurich (the Swiss Federal Institute of Technology). He earned a PhD in physics and was managing director of the Institute of Transport & Economics at Dresden University of Technology in Germany. He is internationally known for his work on pedestrian crowds, vehicle traffic, and agent-based models of social systems. Furthermore, he coordinates the FuturICT Initiative, which focuses on the understanding of techno-socioeconomic systems, using Smart Data. His work is documented in hundreds of scientific articles, keynote lectures, and media reports worldwide. Helbing is an elected member of the World Economic Forum's Global Agenda Council on Complex Systems and of the prestigious German Academy of Sciences "Leopoldina." He is also Chairman of the Physics of Socio-Economic Systems Division of the German Physical Society and cofounder of ETH Zurich's Risk Center.

From computational social science to global systems science

I will give an overview of our work at the Professorship of Computational Social Science (COSS), which aims to integrate social research in three ways:

- By bringing modeling and computer simulation of social processes and phenomena together with related empirical, experimental, and data-driven work
- By combining the perspectives of different scientific disciplines (e.g. socio-physics, social, computer and complexity science)
- By bridging fundamental and applied work.

The research focus has quickly moved from studying pedestrian crowds and vehicle traffic to social coordination, cooperation, norms, crime and conflict as well as collective opinion formation and the wisdom of crowds. The team uses methods such as evolutionary game theoretical modeling, agent-based computer simulations, as well as lab and web experiments.

The analysis of Big Data, cultural science, real-time data mining, the creation of self-organizing systems, innovation, and the analysis of how science works, are further subjects of interest. The COSS team is also engaged in the study of systemic risk, and possible measures of risk reduction and disaster response, including earthquake resilience and advice on stemming the spread of epidemics.

- New Methods for Understanding Complex Systems, Day 2



JILL JÄGER

Dr. Jill Jäger received her BSc degree in environmental sciences from the University of East Anglia, UK, in 1971. In 1974 she was awarded her PhD in geography, focusing on climatology, from the University of Colorado, USA.

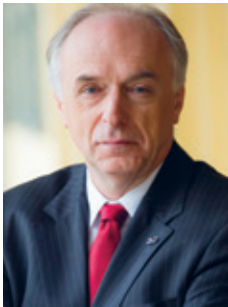
In 1987 Jäger became project leader at the Stockholm Environment Institute, Sweden, and in 1991 she became director of the Climate Policy Division of the Wuppertal Institute for Climate, Environment and Energy, Germany. She joined IIASA in 1994, where she was deputy director. From 1994 until 1998, Jäger was executive director of the International Human Dimensions Programme on Global Environmental Change from 1999 until 2002. She joined the Sustainable Europe Research Institute, Austria, in 2004, where she was senior researcher until 2008.

Jäger has an extensive publication record, her research themes spanning energy and climate; biodiversity; global responsibility; public and stakeholder participation; policy integration; and linkages between knowledge and action for sustainable development.

Methodological advances for transformative research

Complex and persistent problems of unsustainability require new approaches and new tools. How can science best contribute to finding solutions for these problems? Using examples from ongoing projects, this talk will distinguish between conventional research and transformative research, and show some new methodological advances that are being tested in participatory settings. These advances are based on the recognition of the following needs: to focus on solutions, not only problems; to integrate motives, values, human nature and agency; to focus on deep causes and social-ecological interactions, not only symptoms; to link local/situated integrated solutions of multiple problems to global processes; and to address institutional and behavioral change.

■ Requirements for Methodological Advances in Systems Analysis, Day 1



PAVEL KABAT

Professor Dr. Pavel Kabat is Director General and CEO of IIASA, an independent, international science and science-to-policy institute with 23 member countries, more than 300 international staff, and a global research network of ~2,500 scholars and almost 300 partner institutions. He is also full professor of Earth System Science at Wageningen University in the Netherlands, founding chair and director of the Royal Dutch Academy of Sciences and Arts Institute for Integrated Research on the Wadden Sea Region (Wadden Academy), a member of the Leadership Council for the United Nations Sustainable Development Solutions Network, and cofounder of the Alpbach–Laxenburg Group.

Kabat is an award winning mathematician and hydrologist, whose almost 30-year research career has covered earth system science and global change, with a specific focus on land-atmosphere interactions, climate hydrology, water cycle, and water resources. During this time he has authored or coauthored over 300 refereed publications, including nine books.

- Opening Session: Welcome, Day 1
- Music and Science: IIASA's Goodwill Ambassador, Vienna Philharmonic (Introduction), Day 1
- Public Lecture (Introduction & chair), Day 2
- Closing Session (Introduction & chair, Closing remarks), Day 3



RALPH L. KEENEY

Professor Ralph L. Keeney received his PhD from the Massachusetts Institute of Technology. He is research professor emeritus of Business Administration at Duke University, USA, and professor emeritus of Industrial and Systems Engineering at the University of Southern California, USA. He is an authority on decision analysis, decision making with multiple objectives, and value-focused thinking. His research interests include value models involving multiple objectives, risk analysis involving life-threatening risks, structuring decisions, and creating innovative alternatives. During his professional career, Keeney has consulted on a wide range of decisions including corporate management problems, public policy, risk analyses, and energy decisions. Keeney's books, which have been translated into numerous languages, include "Decisions with Multiple Objectives" with Howard Raiffa (1976, 1993), "Value-Focused Thinking: A Path to Creative Decisionmaking" (1992), and "Smart Choices: A Practical Guide to Making Better Decisions", with John S. Hammond and Howard Raiffa (1999). He recently received an honorary doctorate from the University of Waterloo in Canada and is a member of the US National Academy of Engineering.

Constructing value models for applied systems analysis

There is a significant gap between the input and output information of many systems analysis models and what decision makers can control and care about. What they can control is the choice of policies, not the scenarios. What they care about is how well their objectives are met, which may include how well their stakeholders' concerns are addressed. To enhance the usefulness of applied systems analyses to decision makers requires expanding the breadth of these analyses to have the decision makers' policies as inputs, and the impacts that they directly care about as outputs. These outputs need to be linked to value models that quantitatively represent the preferences of a decision maker as an equation. A value model includes the fundamental objectives of the decision maker, its risk attitudes, and its value trade offs. This presentation describes the steps required to construct a useful and practical value model. For each step, the information required is indicated and how the information should be obtained is discussed. In addition, common pitfalls and mistakes at each of the steps are indicated.

■ Howard Raiffa Session, Day 2



L. ROBIN KELLER

Professor L. Robin Keller, president of the Institute for Operations Research and the Management Sciences (INFORMS), conducts decision analysis research on multiple attribute decision making; fairness; perceived risk and planning protection against terrorism; and environmental health and safety risks. A full professor of Operations and Decision Technologies in the Merage School of Business at the University of California, Irvine, USA, she teaches management science, decision analysis, and decision theory. She earned a PhD and MBA in management science and a BA in math from the University of California, Los Angeles, USA. She has served as the Doctoral Program director and associate dean for the MBA Program and for Research. She was program director for the US National Science Foundation Decision, Risk, and Management Science Program. Keller was also the editor-in-chief of the journal *Decision Analysis* from 2007-2012, a founding director-at-large of INFORMS, TIMS vice president finance, and Decision Analysis Society chair. She is an INFORMS fellow and was awarded the Kimball Medal.

Multi-objective, multi-stakeholder decision analysis

A key component of systems analysis is examining the perspectives and actions of multiple stakeholders. Constructing a hierarchy of each stakeholder's objectives with respect to a decision situation can provide insights on areas of agreement and disagreement. Sometimes, one objectives hierarchy is suitable for a set of stakeholders, and differences in opinions across stakeholders can be characterized by differences in the multiple objectives' weights. Examples include planning for protection against radioactive iodine releases in nuclear incidents and analysis for the merger of the Operations Research Society of America and the Institute of Management Sciences to become INFORMS. In other cases, an objectives hierarchy will be constructed for each stakeholder because their objectives are so different that construction of separate hierarchies better represents their divergent perspectives. Examples include a tuna fish supplier source selection decision (from the perspectives of the StarKist company, environmentalists, and the San Diego tuna fishing fleet), a prostate cancer treatment decision (of former Intel CEO Andy Grove, his family, his company, and his doctors), and the potential siting of a new Home Depot building supply store.

Having modeled stakeholders' objectives, dynamic sensitivity analysis can be conducted using sliders in Excel on the objectives' weights, to rapidly see how the preferred action

may change with weight changes. It would also be possible to examine the perceived fairness across stakeholders of anticipated environmental changes or proposed societal policies. Just as groups may differ in objectives, they may also differ in their perception of risks. In particular, scientists and laypeople often judge the magnitude of risks very differently.

- Opening Session: Welcome, Day 1
- Addressing Diversity in Social Systems, Day 3



NADEJDA KOMENDANTOVA-AMANN

Dr. Nadejda Komendantova is a coordinator of the research theme “Governance in transition” within the Risk, Policy and Vulnerability Program at IIASA. Her research interests include participatory and multi-risk governance, based on the understanding of views and risk perceptions of involved stakeholders, of governance structures, market and civil society as well as social institutions and political processes towards more adaptive and inclusive governance approach, which is central to the science-policy interface. Komendantova is currently a principal investigator of the project “Linking climate change mitigation, energy security and regional development in climate and energy model regions in Austria” (LINKS) project. She is also a work package leader in the project “MENA Sustainable ELECTricity Trajectories Energy for sustainable development in North Africa and the Middle East” (MENA-SELECT) supported by the German Federal Ministry for Economic Cooperation and Development (BMZ).

The work of Komendantova includes more than 60 publications, among them in the Global Corruption Report (Transparency International), the Global Assessment Report (GAR) report, input papers for the United Nations Office for Disaster Risk Reduction (UNISDR), the chapter on risk governance for the global report issued by the Global Facility for Disaster Reduction and Recovery of the World Bank, and contribution to the Global Renewable Energy Report (REN21), as well as a number of other peer-reviewed publications. Her works were also granted awards from the Academic Council of the United Nations as well as the Julius Raab Foundation. She received a number of invitations to speak at high-level forums such as the Directorate General for Research and Innovation of the European Commission, NATO, Energy Community Secretariat and Energy Charter Forum, as well as Economic and Environmental Committee Meetings of the Organization for Security and Cooperation (OSCE) in Europe.

- Closing Session (Panel member), Day 3



MARTIN LEES

Currently senior adviser to the president of COP 20 and moderator of the Gorbachev Task Force on Climate Change, Martin Lees is Rector Emeritus of the University for Peace of the United Nations and has been UN ASG for Science and Technology for Development. Over 35 years of cooperation with China, he initiated the establishment of the China Council for International Cooperation on Environment and Development in 1992. Lees was responsible in 1972 for the launching of the OECD “InterFutures” Project on the Future of the Advanced Industrial Societies in Harmony with that of the Developing Countries and, in 1984, of the InterAction Council of Former Heads of State and Government. Between 1990 and 1996 he developed and implemented programmes in the Newly Independent States of the Former Soviet Union. From 1995 – 2008 he was moderator of the International Advisory Board of the Toyota Motor Corporation and, from 2008 to 2010, secretary general of the Club of Rome.

- Closing Session (Panel member), Day 3



ROBERT LEMPERT

Robert Lempert is a senior scientist at the RAND (Research and Development) Corporation and director of the Frederick S. Pardee Center for Longer Range Global Policy and the Future Human Condition. His research focuses on decision making under conditions of deep uncertainty, with an emphasis on climate change, energy, and the environment. Lempert and his research team assist a number of natural resource agencies in their efforts to include climate change in their long-range plans. He has also led studies on national security strategies and science and technology investment strategies for clients such as the White House Office of Science and Technology Policy.

Lempert is a fellow of the American Physical Society, a member of the Council on Foreign Relations, a member of the US National Academy of Sciences Panel on Assessing the Impact of Climate Change on Political and Social Stresses, and a lead author for Working Group II of the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report and for the IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation.

A new decision science for complex systems: A decade of enabling tools

Quantitative information is often necessary for good decisions. But successful decision support must also enable decision makers to engage effectively with the information. This can prove a particular challenge for so-called “wicked problems,” which are characterized by the presence of deep uncertainty, contested interests and values, unclear system boundaries, and often non-linear dynamics. In addition, as the ability to simulate complex systems improves, so too does the need for quantitative decision-support methods that can make use of the unique types of information such simulations provide about a fast-changing, contingent, often hard-to-predict world. In recent years, methods such as robust decision making and scenario discovery have enabled significant advances in decision support under such conditions. These approaches are made possible by advanced computational capabilities, data analysis, and visualizations methods and are specifically designed to help identify and adjudicate trade-offs in the presence of deep uncertainty. Drawing on examples from climate change and other policy areas, this talk will survey the history and current application of robust decision making and scenario discovery and address directions for the future.

■ Devising integrated Solutions, Day 3



SIMON A. LEVIN

Professor Simon A. Levin received his BA from Johns Hopkins University, USA, and his PhD in mathematics from the University of Maryland, USA. Since 1992, he has been at Princeton University, USA, where he is currently George M. Moffett professor of biology at the Department of Ecology and Evolutionary Biology. He retains an adjunct professorship at Cornell University, where he worked from 1965 to 1992 in roles including director of the Ecosystems Research Center, the Center for Environmental Research and the Program on Theoretical and Computational Biology. His research interests are in understanding how macroscopic patterns and processes are maintained at the level of ecosystems and the biosphere, in terms of ecological and evolutionary mechanisms that operate primarily at the level of organisms; in infectious diseases; in ecological economics; and at the interface between basic and applied ecology.

Levin is an award-winning ecologist, who has mentored more than 100 graduate students and postdoctoral fellows. In 2014 he won the prestigious Tyler Prize for Environmental Achievement for his research revealing the complexity of, and relationships between,

species and ecosystems, and in 2005 was named a recipient of the Kyoto Prize in honor of his contributions to environmental science. From 2003 to 2008, he chaired the Governing Council for IIASA, and became an IIASA distinguished visiting fellow in 2014.

Current revival of systems thinking and major challenges for systems analysis

Fundamental questions in applied systems analysis involve complex adaptive systems, in which localized interactions among individual agents give rise to emergent patterns that feed back to affect individual behavior. In such systems, a central challenge is to scale from the “microscopic” to the “macroscopic,” in order to understand the emergence of collective phenomena, the potential for critical transitions, and decision conflicts between levels of organization. This lecture will suggest that studies of emergence, scaling, and critical transitions in physical systems can inform the analysis of similar phenomena in ecological systems, while raising new challenges for theory.

■ Framing Session: Keynote Lecture, Day 1



WOLFGANG LUTZ

Professor Wolfgang Lutz is Founding Director of the Wittgenstein Centre for Demography and Global Human Capital (a collaboration between IIASA, the Austrian Academy of Sciences and the WU-Vienna University of Economics and Business). He joined IIASA in October 1985, where he is Program Director of the World Population Program. Since 2002 he is also director of the Vienna Institute of Demography of the Austrian Academy of Sciences and since 2008, Full Professor of Applied Statistics (part time) at the WU. He is also Professorial Research Fellow at the Oxford Martin School for 21st Century Studies.

Lutz studied philosophy, theology, mathematics and statistics at the Universities of Munich, Vienna, and Helsinki and holds a PhD in Demography from the University of Pennsylvania (1983) and a second doctorate (Habilitation) in Statistics from the University of Vienna.

He has worked on family demography, fertility analysis, population projection, and the interaction between population and environment. He has been conducting a series of in-depth studies on population-development-environment interactions in Mexico, several African countries, and Asia. He is the author of the series of world population projections produced at IIASA and has developed approaches for projecting education and human capital. He is also principal investigator of the Asian MetaCentre for Population and Sustainable Development Analysis. Lutz is author and editor of 28 books and more than 200 refereed articles, including seven in *Science* and *Nature*. In 2008 he received an ERC Advanced Grant, in 2009 the Mattei Dogan Award of the IUSSP, and in 2010 the Wittgenstein Prize, the highest Austrian science award. He is elected full member of the Austrian Academy of Sciences and of the German National Academy Leopoldina as well as a member of the Committee on Population of the US National Academy of Sciences.

What should be the sustainability criteria in systems models?

In comprehensive systems models human beings are clearly agents of change. Their behaviors tend to have social, economic, or environmental impacts. Here it is important to explicitly consider the fact that not all human agents are the same and there is considerable heterogeneity. The new set of Shared Socioeconomic Pathways produced by IIASA in collaboration with several other global change research institutes operationalize this heterogeneity with respect to age, sex, level of education, and place of residence.

But humans are not only the drivers of change. They are also affected by the changes that are being modeled. Many of those social, economic, and environmental changes

also feedback on human wellbeing. Hence the long-term development of well-defined indicators of human development can also serve as a criterion for the sustainability of the modeled processes. In this context the newly proposed indicator of Empowered Life Years will be explained and discussed with respect to its suitability as a criterion variable. It is based on the idea that being alive (i.e., avoidance of premature mortality) is a basic prerequisite for enjoying any quality of life but that at the same time mere survival is not good enough and that the years of life need to be weighted with empowerment indicators such as health, being able to read, being out of poverty, or being "happy."

■ Requirements for Methodological Advances in Systems Analysis, Day 1



MAURO MARTINO

Mauro Martino is an Italian expert in data visualization based in Boston. He created and leads the Cognitive Visualization Lab at IBM Watson in Cambridge, Massachusetts, USA. Martino's data visualizations have been published in the scientific journals *Nature*, *Science*, and the *Proceedings of the National Academy of Sciences*. His projects have been shown at international festivals including Ars Electronica, and art galleries including the Serpentine Gallery, UK, GAFTA, USA, and the Lincoln Center, USA.

Data visualization and artificial intelligence: The real time exploration of unstructured big data

In this talk we explore the limits of data visualization and why we need to use more and more technology from the world of artificial intelligence. Martino shows us some of the innovations in this field. During the presentation the audience can play with three different DataViz: 1) the exploration of news in real-time; 2) the exploration of a large dataset of videos; 3) the analysis of relationships between entities and topics in a specific corpus of data.

■ New Methods for Understanding Complex Systems, Day 2



DAVID MCCOLLUM

Dr. David McCollum is a researcher with the IIASA Energy Program. His main fields of scientific interest include techno-economic analysis of advanced energy and transport technologies and the development and application of energy-economic and integrated assessment models. His research attempts to inform national, regional, and global energy and environmental policies on matters related to climate change, sustainable transport, energy security, and air pollution. To this end, McCollum performs long-term scenario analyses, particularly focusing on potential transitions for the energy system and the complex synergies and trade-offs between multiple energy objectives. In 2011 he received his doctorate in transportation technology & policy from the Institute of Transportation Studies in the University of California, Davis, USA, following the completion of an MSc in agricultural & resource economics from the same institution, and a BSc in chemical engineering from the University of Tennessee, USA. McCollum authored multiple chapters of the Intergovernmental Panel on Climate Change Fifth Assessment Report (Working Group III).

Harnessing systems analytical tools to develop sustainable energy scenarios for the 21st century

Reaching the economic, environmental, and sustainability objectives of all societies requires overcoming several major energy challenges. The scenario pathways highlighted in this talk describe transformative changes toward these goals, taking a broad view

of the major energy sustainability challenges of the 21st century. The overarching goal of the work is to provide policy guidance on how to facilitate the transformation of the energy system to achieve these multiple energy objectives. Particular focus is given to their complex interlinkages, namely the synergies and trade-offs between the objectives and the quantification of co-benefits. The work approaches the global transition toward sustainable development in an integrated, holistic manner, exploring the dynamics through the lens of systems analysis.

■ Devising Integrated Solutions, Day 3



BORIS MIRKIN

Boris Mirkin is a professor at the Faculty of Computer Science, National Research University Higher School of Economics, Russia. He holds a PhD in Computer Science and a DSc in Systems Analysis from Russian Universities. In 1991-2010 he traveled extensively, taking visiting research appointments in France, USA, Germany and a teaching appointment at the Birkbeck University of London, UK.

He develops methods for clustering and interpretation of complex data from the “data recovery” perspective. Currently these approaches are being extended to automation of text analysis problems, including the development and use of hierarchical ontologies.

Data summarization at clustering and ranking

This talk introduces the concept of data summarization as a problem of data approximation to review such approaches to systems/data analysis and visualization as singular-value decomposition (SVD), principal component analysis (PCA), latent Dirichlet allocation (LDA) and deep learning networks (DL).

I then focus on the two data summarization problems in the title. An extension of SVD/PCA to cluster analysis appears to lead to k-means, the most popular method in data clustering, and an equivalent criterion leading to Anomalous clustering that proved superior in our computational experiments.

A data summarization approach to multicriteria decisions leads to a novel method for automated ranking. Its application to the issues of evaluating a scientist’s research impact is discussed, including a method for direct evaluation of the quality of research results by mapping the results to a hierarchical taxonomy of the field. This subject is illustrated by an in-house analysis of research results by 30 leading data analysis researchers. The talk concludes with a discussion of implementation of the methods using contemporary big-data analysis platforms such as Hadoop-Map-Reduce and the like.

■ New Methods for Understanding Complex Systems, Day 2



YAMIR MORENO

Professor Yamir Moreno got his PhD in physics in 2000 from the University of Zaragoza, Spain. Shortly afterwards, he joined the Condensed Matter Section of the International Centre for Theoretical Physics in Trieste, Italy as a research fellow. Since 2003 he has been head of the Complex Systems and Networks Lab and is also affiliated to the Department of Theoretical Physics of the Faculty of Sciences at the University of Zaragoza. He is the deputy director of the Institute for Bio-computation and Physics of Complex Systems and member of its Government Board and Steering Committee.

Recently, he has been working on several problems such as: the study of nonlinear dynamical systems coupled to complex structures; transport processes and diffusion with applications in communication and technological networks; dynamics of virus and rumors propagation; game theory; systems biology (the TB case); the study of more complex

and realistic scenarios for modeling infectious diseases; synchronization phenomena; the emergence of collective behaviors in biological and social environments; the development of new optimization data algorithms; and the structure and dynamics of socio-technical and biological systems.

From small to big data: The physics of human behavior

Physics has been extremely successful in describing our natural world, from very small to very large scales. However, as we will argue in this talk, the study of human collective behavior is not as easy as dealing, for instance, with ideal gases. The reasons are multiple, for example, we do not know the laws describing most human behaviors and in many dynamical processes details really matter. This calls for the analysis of human behavioral data, in some cases small, in others big, but also at intermediate scales. Through the description of three different examples of human collective behavior and using data at different scales, we will identify the experimental (data) and theoretical challenges in the study of social systems, and propose a way to tackle such problems.

■ Trans-disciplinary Inspiration in Systems Thinking, Day 1



RAYA MUTTARAK

Dr. Raya Muttarak joined the World Population (POP) Program at IIASA as a research scholar in September 2011. After her MA in International Relations at Waseda University (Japan), she obtained her MSc and DPhil in sociology from the University of Oxford (UK) in 2008. From September 2008 to August 2011, Muttarak was a postdoctoral research fellow (Max Weber Programme & Marie Curie Intra-European Fellowship) at the European University Institute in Florence, Italy. She is also an associated researcher at the Department of Epidemiology, Mario Negri Institute for Pharmacological Research in Milan, Italy.

Her research interests lie in the intersection of social inequality, differential vulnerability, and environmental change. Her recent research project focuses on demographic differential vulnerability: 1) to impacts of natural disasters/climate change; and 2) in ability to respond and cope with consequences of extreme weather events. Muttarak also works on attitudes toward climate change and environmental behaviors. Furthermore, she is also actively engaged in empirical studies on a variety of topics ranging from the effects of the economic crisis on health, immigrants' integration, to social networks and fertility.

■ Closing Session (Panel member), Day 3



NEBOJSA NAKICENOVIC

Professor Nebojsa Nakicenovic is Deputy Director General/Deputy CEO of IIASA and former Full Professor of Energy Economics at the Vienna University of Technology

Among other positions, Nakicenovic was Director of the Global Energy Assessment, Member of the United Nations Secretary General High-Level Technical Group on Sustainable for Energy for All Initiative; Member of the Advisory Council of the German Government on Global Change (WBGU); Co-Chair of the Global Carbon Project; Coordinating Lead Author of the IPCC, and OMV Resourcefulness Advisory Board.

Nakicenovic has published more than 300 publications and has served on over ten Journal Editorial Boards.

Nakicenovic holds bachelors and masters degrees in economics and computer science from Princeton University, New Jersey, USA and the University of Vienna, where he also completed his PhD. He also holds Honoris Causa PhD degree in engineering from the Russian Academy of Sciences.

Among Nakicenovic's research interests are the long-term patterns of technological change, economic development and response to climate change and, in particular, the evolution of energy, mobility, information and communication technologies.

Recent applications of systems analysis for achieving sustainable futures for all on a safe planet

The provision of sustainable and affordable energy, water, and food services can be linked directly with the key global challenges including the achievement of the sustainable development goals (SDGs). Taking action on the energy-water-food nexus will ameliorate central global challenges. For this, it is essential that the nexus and other dimensions needed to achieve decent and sustainable living for all become a development goal in its own right, as a systems concept. Treating the 17 SDGs adopted by the UN individually will hamper the realization of synergies and avoidance of conflicts and implementation barriers.

Fortunately, there exist combinations of resources, technologies, lifestyles and policy frameworks that could provide a number of pathways toward fulfilling SDGs and achieving a long-term transformation toward sustainable future for all to the middle of the century and beyond. All of them imply a fundamental decarbonization and improved efficiencies of all human activities. Practically, this is about doing more with less. It is a paradigm-changing transformation.

The dynamics of transformational change cannot be planned in detail; they are inherently unpredictable with emergent developments and dependent on human intentionality. The response strategies require deep systems understanding with adaptive approaches. The potential multiple-benefits of the transformation are enormous, ranging from improved human health to sustainable lifestyles. A possible conclusion is that a new systems science for policy is needed to achieve transformational change. This is inherently normative and consistent with the emerging new social contract to achieve decent living for all within the boundaries of keeping the planet safe.

■ Framing Session: Keynote Lecture, Day 1



LUCIANO PIETRONERO

Professor Luciano Pietronero studied physics in Rome and was a research scientist at Xerox Research in Webster in 1974 and at the Brown Boveri Research Center, Switzerland, from 1975 to 1983. He then moved to University of Groningen, the Netherlands, where he was professor of Condensed Matter Theory (1983-87). Since 1987 he has been a professor of physics at the University of Rome "Sapienza", Italy. As founder and director of the Institute for Complex Systems of Consiglio Nazionale delle Ricerche, Italy (2004-2014) he has broad international experience in academic and industrial environments. His scientific research is of both a fundamental and applied nature, with a problem-oriented, interdisciplinary perspective aimed at developing novel and original views in all areas. His interests extend to condensed matter theory; high-temperature superconductivity; statistical physics; fractal growth; self-organized-criticality; complex systems and its interdisciplinary applications. He is also a leader of a generation of young scientists who are protagonists of the complexity scene internationally and in 2008 he received the Fermi Prize, the highest award of the Italian Physical Society.

New metrics for economic complexity: Measuring the intangible growth potential of countries

Economic complexity refers to a new line of research which portrays economic growth as a process of evolution of ecosystems of technologies and industrial capabilities. Complex

systems analysis, simulation, systems science methods, and big data capabilities offer new opportunities to empirically map technology and capability ecosystems of countries, industrial sectors and companies, and analyze their structure, understand their dynamics and measure the economic complexity. This approach provides a new vision of a data-driven fundamental economics in a strongly connected, globalized world.

In particular, here we discuss the COMTRADE dataset which provides the matrix of countries and their exported products. According to the standard economic theory, the specialization of countries towards certain specific products should be optimal. The observed data show that this is not the case and that diversification is actually more important. The situation is different for companies or sectors which seem instead to specialize only on few products.

The crucial challenge is then how to turn these qualitative observations into quantitative variables. We have introduced a new metrics for the "Fitness of countries" and the "Complexity of products," which is a sort of economic version of the Google page-rank approach. Direct comparison of the Fitness with the country's GDP gives an assessment of the non-expressed potential of the country. This can be used as a predictor of GDP evolution or stock index and sectors performances. These results are also useful for risk analysis, planning of industrial development and strategies to exit from the "poverty trap." Analogously, the Complexity of products can be compared with its added value, also providing new information.

The dynamics in the GDP-Fitness plane reveals a heterogeneous structure and certain areas behave in a laminar way (high predictability) while others appear turbulent (low predictability). This situation requires an analysis inspired by the theory of Dynamical Systems and it is not appropriate to use the usual regressions.

Recently, we have also considered the extension of these ideas to the "Fitness of companies" which are instead mostly specialized in terms of products. This requires different datasets and a new algorithm. The implication of the present study for the general problem of "Big Data Science" will be discussed.

■ Trans-disciplinary Inspiration in Systems Thinking, Day 1



PRABHAT RANJAN

Professor Prabhat Ranjan is currently heading the Government of India's Technology Think Tank (TIFAC) as its executive director. TIFAC represents India as its National Member Organization (NMO) for IIASA and Ranjan also serves on the IIASA Council as a member.

Ranjan obtained his PhD in modeling and simulation of Nuclear Fusion reactors at Lawrence Berkeley Laboratory from University of California, USA. Until 2002 he worked fulltime on Nuclear Fusion at National Labs in India.

Since then, Ranjan has served as a professor at the Dhirubhai Ambani Institute of Information and Communication Technology (DA-IICT), Gandhinagar for 11 years. His research area was "Embedded Systems and Sensor Networks" and he applied this to planetary exploration, wildlife tracking, nuclear fusion, healthcare, and agriculture. His work on assistive technology to help people with severe disability has brought smiles to many faces.

■ The Art and Craft of Systems Analysis (Introduction & chair), Day 1 & 2



SERGIO RINALDI

Sergio Rinaldi is professor emeritus of system theory at the Department of Electronics, Information and Bioengineering of the Politecnico di Milano, Italy and is a research scholar at IIASA. He is the author of 200 peer reviewed papers and of seven books, and associate editor of International Journal of Bifurcation and Chaos, Ecological Modelling, and Applied Mathematics and Computation. He has been a visiting professor at Stanford, Berkeley, Vancouver, Kyoto, Wien, and Linz and served as director of the Research Center for Environmental Modelling, Politecnico di Milano, and professor of systems modeling at Alta Scuola Politecnica, Italy. Rinaldi was awarded the Italgas Prize for Scientific Research and Innovation in 1988 and the Calabria Prize for Literature and Science in 1996.

Modeling love dynamics

By making reference to recent contributions collected in a forthcoming book, it is shown how love stories—a vital issue in our lives—can be tentatively described with classical mathematics. Focus is on the derivation and analysis of reliable models that allow one to formally describe the expected evolution of love affairs from the initial state of indifference to the final romantic regime. The models are in full agreement with the basic philosophical principles of love psychology. Particular attention is given to the role played by appeal in shaping the evolution of love stories and in structuring human populations. The presentation is purely theoretical and focused on romantic relationships between important classes of individuals identified by particular psychological traits. But specific love stories described in classical poems or in worldwide famous films (e.g., *Cyrano de Bergerac*, *Gone with the Wind*) are also briefly discussed to highlight the power of the systems analysis approach.

■ Addressing Diversity in Social Systems, Day 3



STEPHEN ROBINSON

Stephen M. Robinson is Professor Emeritus of Industrial and Systems Engineering and of Computer Sciences at the University of Wisconsin-Madison, on whose faculty he served during 1972-2007. Robinson also holds the rank of Colonel (Retired) in the Army of the United States. His research specialty is in variational analysis and mathematical programming: methods for making the best use of limited resources, applied in logistics, transportation, manufacturing, and many other areas. He is author, coauthor, or editor of seven books and more than 100 scientific research papers, and has directed numerous funded research projects at the University. His accomplishments have been recognized by the award of the honorary doctor's degree from the University of Zürich, Switzerland, the George B. Dantzig Prize of the Mathematical Programming Society and the Society for Industrial and Applied Mathematics (SIAM), the John K. Walker Jr. Award of the Military Operations Research Society, and the George E. Kimball Medal of the Institute for Operations Research and the Management Sciences (INFORMS). He is a member of the National Academy of Engineering, a National Associate of the National Research Council, a Fellow of INFORMS, and a Fellow of SIAM. He served as President of INFORMS in 2014.

■ Closing Session (Panel member), Day 3



ELENA ROVENSKAYA

Dr. Elena Rovenskaya, Advanced Systems Analysis Program director at IIASA, is also a research scholar at the Optimal Control Department of the Faculty of Computational Mathematics and Cybernetics, Lomonosov Moscow State University, Russia. Her scientific interests lie in the fields of theory of optimal control, ill-posed problems, and economic-environmental modeling. Rovenskaya graduated in 2003 from the Faculty of Physics, Lomonosov Moscow State University and received her PhD in 2006 from the Faculty of Computational Mathematics and Cybernetics at the same university. The title of her PhD thesis was "On solving the problem of finding the optimal compatibility parameter value for a class of equations in a normalized space." Currently Rovenskaya is working on novel economic growth and renewable natural resource management models.

- Opening Session: Welcome, Day 1
- New Methods for Understanding Complex Systems (Introduction & chair), Day 2
- Closing Session: Conference Synthesis and Outlook for Systems Analysis, Day 3



WERNER RÖMISCH

Professor Werner Römisch received a mathematics diploma in 1971 and a PhD in 1976, both from the Humboldt-University, Germany. In 1985 he received a second doctorate (Habilitation) at the same university and a full professorship in 1993. His research is mainly in stochastic optimization, with side interests in stochastic equations and risk, and applications in energy and revenue management.

Energy systems under uncertainty: Modeling and computations

We consider the following energy systems, discuss modeling issues and related mathematical challenges:

- Yearly planning of production and trading of electricity for a municipal power system under uncertainty,
- Evaluation of gas network capacities under demand uncertainty.

We present important features of the underlying power and gas systems and provide some insight of the relevant mathematical models. Both models are large scale, contain mixed-integer decisions and linear and nonlinear constraints, respectively. The common mathematical challenge is the need for uncertainty quantification. While a stochastic process modeling electricity market prices as well as electricity and heat demand has to be quantified in (a), the gas consumption at a large number of network exits is modeled in (b). Huge data sets are available in both cases. Methods for approximate uncertainty quantification by representative sets of scenarios and their use as inputs into numerical optimization methods are discussed in some detail and illustrated by computational results. Risk aversion is discussed in case of (a).

- The Art and Craft of Systems Analysis, Day 1



ANDRZEJ RUSZCZYŃSKI

Professor Andrzej Ruszczyński received his PhD and Habilitation degrees in control engineering from the Warsaw University of Technology, Poland, in 1976 and 1983 respectively. Since then, he has worked for the Warsaw University of Technology, the University of Zurich, Switzerland, IIASA, Austria, Princeton University, USA, the University of Wisconsin-Madison, USA, and Rutgers University, USA, where he currently holds the rank of distinguished professor. Ruszczyński is one of the creators of and main contributors to the field of risk-averse optimization, author of the book "Nonlinear Optimization", coauthor of "Lectures on Stochastic Programming" and "Stochastic

Programming,” and author of more than 100 articles in the field of optimization. Ruszczynski has been a plenary speaker at several major international conferences and has held positions in influential scientific societies.

Risk quantification and control: Challenges and opportunities

At first, we shall identify strategic research directions in modern systems engineering. The main part of the talk will focus on one of the key areas: risk. We shall review fundamental approaches to risk quantification in decision problems. We shall discuss their main virtues and the theoretical and numerical challenges associated with their application. Then we shall focus on modeling risk in dynamical systems and discuss the property of time consistency and the resulting interchangeability in risk-averse optimal control models. Special attention will be paid to discrete-time Markov systems and risk-averse dynamic programming equations. During the talk, we shall present specific risk models in engineering, business, and medicine.

■ The Art and Craft of Systems Analysis, Day 2



DON SAARI

Professor Don Saari is an academic with over 40 years' experience of conducting interdisciplinary and international research. His passion is applying mathematics to areas as diverse as people and the universe. His research career began in astronomy where he used mathematics to explore the motion of celestial objects and the evolution of the universe in the years after gaining his PhD in mathematics from Purdue University, USA. Today he applies mathematics to resolving some of the fascinating mysteries coming from the behavioral sciences.

This mix of the physical and social sciences makes Saari an ideal chair for the governing board of an interdisciplinary institute like IIASA. This new role, initially until the end of 2018, complements his positions as distinguished professor of mathematics and economics at the University of California, Irvine, USA, where he also directs the Institute for Mathematical Behavioral Sciences. Saari's international experience will also be of great benefit as he works with the 23 national members that make up the IIASA governing council. Since accepting his first position as a visiting scholar at Swiss Federal Institute of Technology in 1970 he has held international research positions in Brazil, France, Spain, Sweden, and Switzerland as well as at IIASA.

- Opening Session: Welcome, Day 1
- Framing Session (Introduction & chair), Day 1
- Closing Session (Panel member), Day 3



MARTEN SCHEFFER

Marten Scheffer is interested in unravelling the mechanisms that determine the stability and resilience of complex systems. Although much of his work has focused on ecosystems, he also worked with a range of scientists from other disciplines to address issues of stability and shifts in natural and social systems. Examples include the feedback between atmospheric carbon and the earth temperature, the collapse of ancient societies, inertia and shifts in public opinion, evolutionary emergence of patterns of species similarity, the effect of climatic extremes on forest dynamics and the balance of facilitation and competition in plant communities. With the help of a Spinoza award and an ERC advanced grant he founded SparcS and now works on finding generic early warning signals for critical transitions. He is also leading the 'South American Institute for Resilience and Sustainability Studies' SARAS and the Aquatic Ecology and Water Quality Management group at Wageningen University.

Foreseeing critical transitions

Complex systems ranging from ecosystems to financial markets, the brain and the climate can have tipping points where a sudden shift to a contrasting regime may occur. Predicting such critical points before they are reached is extremely difficult. However, work in different fields of science is now suggesting the existence of generic early warning signals that may indicate for a wide class of systems if a critical threshold is approaching. I will review key findings and highlight opportunities as well as challenges in this rapidly emerging research area. I will also discuss barriers and bridges to move to the practical management of risks and opportunities associated to tipping points.

- The Art and Craft of Systems Analysis, Day 2
- Requirements for Methodological Advances in Systems Analysis (Introduction & chair), Day 1



MARY SCHOLES

Mary Scholes, a graduate of the University of the Witwatersrand, is currently a full professor in the School of Animal, Plant and Environmental Sciences and serves as the Director of the Graduate Support Division at Wits.

Her research activities focus on soil fertility, food security and biogeochemistry in savannas, plantation forests and croplands. Her research funds are mostly sourced from industry and the government and she is currently actively involved in monitoring the impacts, on human health and the environment, of the new power stations in the Waterberg.

She serves as the Chair of IIASA's Science Advisory Committee, vice-chairperson for the International Committee of Climate Change, Agriculture and Food Security as well as the Secretary General for the Scientific Council on Problems in the Environment. She also chairs the advisory board of the Max Planck Institute for Chemistry. These activities involve extensive collaborative research with a number of overseas and local institutes.

- Addressing Diversity in Social Systems (Introduction & chair), Day 3



ANNA SCOLOBIG

Anna Scolobig is senior researcher in the Climate Policy group at ETH Zurich- Swiss Federal Institute of Technology. In her work she addresses questions related to disaster risk reduction and climate change policy. Her focus is on disaster response planning and management and on stakeholder processes to design robust adaptation options. She has been conducting extensive empirical research in communities at risk of natural hazards in several European countries. Scolobig has a background in social sciences and was awarded her PhD on integrated vulnerability assessment, from the University of Udine, Italy in 2008. During her PhD she worked as research assistant at the Mass Emergency Programme ISIG, Italy and at the Helmholtz Centre for Environmental research UFZ, Germany. Afterwards she held positions as lecturer at the University of Trieste and postdoctoral research scholar in the Risk, Policy, and Vulnerability Program.

From stakeholder views to policy options

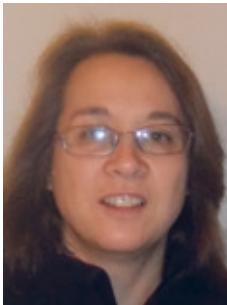
Authors: Scolobig A¹, Linnerooth-Bayer J², Thompson M²

¹Swiss Federal Institute of Technology (ETH) Zurich, Switzerland ²IIASA

Stakeholder participation in policymaking processes can potentially improve their effectiveness, decrease opposition, and help legitimize the outcome. The challenge we address is how to account for stakeholder diversity and conflicting values, worldviews

and rationalities in the pursuit of a compromise policy position. In meeting this challenge, we present a participatory deliberative process involving the public and experts that demonstrates new advances for (1) co-producing policy options, and (2) reaching compromise in a contested policy terrain. The context is a three-year public participatory process on landslide risk management in Italy, where the co-production of technical policy options required transitioning from a one-way expert-determined knowledge model to a two-way participatory model. Experts formulated policy options interactively with stakeholders based on their discourses and story lines. After several facilitated workshops, the diverse public perspectives were conciliated to reach an agreed compromise policy path. We conclude by contrasting this participatory methodology with other approaches for robust decision making.

■ Addressing Diversity in Social Systems, Day 3



LINDA SEE

Dr. Linda See has a PhD in spatial applications of fuzzy logic from the School of Geography, University of Leeds, UK, where she taught for 11 years as a senior lecturer in Computational Geography and GIS. She has an MSc and BSc in physical geography and environmental management from McMaster University and the University of Toronto, Canada. In between her MSc and PhD, she spent one year working at the Max Planck Institute for Atmospheric Sciences in Germany, followed by four years at the Food and Agriculture Organization of the United Nations in Italy on agrometeorology and early warning for food security.

See's research interests include artificial intelligence-based methods (neural networks, fuzzy logic, genetic algorithms, agent-based modeling), GIS, and more recently, gaming and crowdsourcing. As part of the IIASA Ecosystems Services and Management Program she is now working with Steffen Fritz on Geo-Wiki and land cover validation issues. She is an active member of the Geo-Wiki team and has worked on a number of crowdsourcing aspects including quality issues, community building, and a branch of Geo-Wiki concerned with validation of urban land cover.

Mobilizing mass action through mobile devices: Challenges and opportunities for science, policy, and governance

Citizen science and crowdsourcing have become increasingly popular ways of involving citizens in scientific research and for carrying out a variety of micro-tasks. There are many examples of successful citizen science projects and crowdsourcing platforms including the LandMapp project for community-based land tenure mapping; Moabi, which allows citizens to report illegal logging in the Congo jungles, (both of which have been supported by IIASA and WWF (World Wide Fund for Nature)); and Geo-Wiki, a tool for visualization, crowdsourcing, and validation of global land cover, developed at IIASA. This talk will provide a brief overview of citizen science and crowdsourcing followed by the main achievements and lessons learned from the LandMap, Moabi, and Geo-Wiki projects. A number of challenges remain such as how to move citizen participation from data collection to environmental stewardship, and how to scale up these efforts to tap into the large citizen networks and initiatives that are currently ongoing, for example, WWF's Earth hour, which reaches a billion people. We will discuss these and other challenges in light of new opportunities in climate funding and other new sources of private funding, for green businesses, for instance.

■ Devising Integrated Solutions, Day 3



PETR SHEBALIN

Petr Shebalin is a chief scientist at the Institute of Earthquake Prediction Theory and Mathematical Geophysics. Shebalin graduated from the Physics Department of Lomonosov Moscow State University, Russia (1979), and received his PhD in geophysics in 1988 and DSc in 2004. Since 1993 he has served as an invited professor in Institut de Physique du Globe, Paris. He has also worked in ICTP, Trieste, Italy, UCLA and USC, Los Angeles, USA, and USGS, Menlo Park, USA. He developed several earthquake prediction algorithms, including Reverse Tracing of Precursors based on the phenomenon of increase of the earthquakes correlation range prior to large earthquakes. Working in different fields of statistical seismology, in recent years he has concentrated on analysis of earthquake aftershocks. He discovered a direct link between the delay of the onset of the power-law decay of aftershocks (Omori-Utsu law) and the average stress accumulated in the fault of the main shock. He also works on combining different approaches (probabilistic and deterministic) for earthquake prediction/forecasting.

Linking probabilistic and deterministic forecast methods: Systems analysis for predicting earthquakes

Large earthquakes that are considered as extreme events in a complex system – the Earth lithosphere belong to the most dangerous natural disasters. During the last years a significant progress in developing and testing earthquake prediction/forecasting models was demonstrated giving an impulse to start operational forecasts in several countries. However a large gap between the models and decision making still exists. Two directions in developing models are almost independent. Probabilistic models forecast earthquake expected rates in time and space. Usually probabilistic models are based on the analysis of actual earthquake rates. For large earthquakes the forecasted rates are very small, except short periods of aftershocks, and decision making based on tiny probabilities is extremely difficult. Deterministic models select location areas and periods of alarms on the basis of earthquake precursors and/or premonitory patterns. Decision making that is a typical problem of systems analysis is still rather difficult, because of trade-off between false alarms and failures to predict. A synthesis of probabilistic and deterministic techniques made on the basis of the system analysis approach could help in finding effective decision making algorithms.

Here, we propose a method to combine the earthquake forecast rate-based models with any information that could locally increase the forecasted earthquake rates. We use the differential probability gain calculated in the error diagram that evaluates the performance of the input information with respect to the rate-based model. Then, at each point in space and time, the new rate is the product of the current rate times the local differential probability gain. The main advantage of our combining method is its capacity to produce high expected event rates. We demonstrate how the method works on several examples.

■ The Art and Craft of Systems Analysis, Day 1



KARL SIGMUND

Karl Sigmund, born 1945, studied mathematics in Vienna. After postdoc years in Manchester, Paris, and Jerusalem, he became professor in Göttingen University in 1973, and full professor at the University of Vienna in 1974. Since 1984, he has been affiliated with IIASA. Sigmund worked in ergodic theory, dynamical systems, biomathematics and evolutionary game theory. He is author of several books, including 'Games of Life', 'Calculus of Selfishness' and 'The Goedel Album', and he is member of the Austrian, the German, and the European Academy of Science.

A new decision science for complex systems: A decade of enabling tool

Following the lead of Elinor Ostrom, institutions may be viewed as tools for providing positive or negative incentives to overcome social dilemmas such as the tragedy of the commons. The judicious interplay of rewards and penalties, the role of voluntary participation, and the pros and cons concerning peer action and social institutions raise many questions which are interesting from the viewpoints of modelling, analysis, experimentation, and field research. Whereas peer punishment is threatened by pre-emptive strikes and the escalation of conflicts, institutionalized punishment is endangered by corruption.

■ Addressing Diversity in Social Systems, Day 3



PETER M.A. SLOOD

Professor Peter M. A. Slood trained as a physicist (MSc 1983) and chemist (MSc 1983) and followed this with a PhD in informatics (1988) working on early detection of tumour cells, epidemics, and immunity. In 2001 Slood became a full professor of computational science at the University of Amsterdam, the Netherlands, and in 2014 a full professor of complex system simulation and director of the Complexity Institute at Nanyang Technological University, Singapore. In 2010 he was awarded the 'Leading Scientist Award' by the president of the Russian Federation. He also serves as editor in chief of two Elsevier Science journals.

Slood is driven by the ambition to better understand the complex world around us, from the zillions of molecules in the living cell to the billions of human individuals and countless living organisms that constitute our planet, all interacting in nonlinear and often unpredictable ways.

■ Opening Session: Welcome, Day 1

■ Closing Session (Panel member), Day 3



MARK STAFFORD-SMITH

Dr Mark Stafford Smith is based in Canberra, Australia, and looks after coordinating Adaptation Research across CSIRO; he oversees a highly interdisciplinary program of research on many aspects of adapting to climate change, as well as regularly interacting with national and international policy issues. He has over 30 years experience in drylands systems ecology, management, and policy, including senior roles such as CEO of the Desert Knowledge Cooperative Research Centre in Alice Springs. His significant international roles include being past vice-chair of the International Geosphere-Biosphere Programme's Scientific Committee. In 2012 he was co-chair of the *Planet Under Pressure: New Knowledge Towards Solutions* conference on global environmental change in the lead up to Rio+20. In 2013 he was appointed chair of the inaugural Science Committee for *Future Earth*, which aims to help coordinate research towards global sustainability worldwide.

■ Trans-disciplinary Inspiration in Systems Thinking (Introduction & chair), Day 1



XIJIN TANG

Dr. Xijin Tang received the Bachelor's degree in computer science and engineering from Zhejiang University in 1985, the Master's degree in management science and engineering from the University of Science and Technology of China in 1992, and the Doctoral degree in management science and engineering from the Institute of Systems Science, Chinese Academy of Sciences (CAS) in 1995. She developed several decision support systems for water resource management, weapon system evaluation, e-business evaluation, etc. during her early system research and practice. Her recent research interests include: meta-synthesis and advanced modeling, decision support systems, opinion dynamics and opinion mining, systems approaches to societal complex problems, knowledge management and creativity support systems. She co-authored and published two influential books on meta-synthesis system approach and an oriental systems approach in Chinese. She was one of 99 who won the 10th National Award for Youth in Science and Technology in China in 2007. Currently, Dr. Tang is the Vice President and General Secretary of the International Society for Knowledge and Systems Sciences.

Perceiving societal risk from online community concerns

Currently, China is undergoing great social transformations and facing emerging "wicked problems" across environment, food safety, governance, health, inequalities, national security, population, urbanization, etc., which cover all aspects of social living. The public is exposed to news of these developments in real time via internet search news, BBS posts, blogs, and microblogs, especially in the Web 2.0 era. Using a catalogue of Chinese societal risk constructed by Chinese sociopsychologists, we map those online community concerns into respective societal risks and aggregate all risks so as to understand online societal risk perception. In this way we augment the traditional social psychological approach.

Basic ideas and 5-year research results are addressed in this talk. Illustrations of measuring the societal risk level with the latest dataset of 3-year daily hot search Baidu (the biggest Chinese search engine) news words are given, together with the difficulties of such a trial over BBS posts from the biggest Chinese BBS portal. Humans' cognitive difference in societal risk perception, unbalanced samples of risk class, and continual emerging events are three principal challenges to the machine learning practice in this study. Though much effort has been put into these practical technical tasks via text mining, more consideration of the cognitive mechanism of societal risks, the identification of key factors, and risk evolution along a hazard development process based on advanced machine learning are expected.

■ Devising Integrated Solutions, Day 3



STEFAN THURNER

Stefan Thurner is full professor in science of complex systems at the Medical University of Vienna, where he chairs Section for Science of Complex Systems. An external professor at the Santa Fe Institute, USA, since 2007, he has also been a part-time senior researcher at IIASA since 2010.

Thurner obtained a PhD in theoretical physics from the Technical University of Vienna in 1995, and a PhD in economics from the University of Vienna in 2001. He held postdoc positions at Humboldt Universität zu Berlin and Boston University before he joined the faculty of the University of Vienna in 1999 and later the Medical University. He obtained his habilitation in theoretical physics in 2001. With his engagement with the Santa Fe Institute he shifted his focus from theoretical physics to biological and complex systems, which are now his main research areas.

Since 1995 Thurner has published more than 170 scientific articles in fundamental physics, applied mathematics, complex systems, life sciences, bioinformatics, economics and lately in social sciences. He holds two patents.

Management of systemic risk

Systemic risk in financial markets arises either through synchronized behavior of agents, or because of the interconnectedness of agents through financial contracts. We show that the systemic risk level of every agent in the system can be quantified by simple network measures. With actual central bank data for Austria and Mexico we are able to compute the expected systemic loss for an economy, a number that allows us to estimate the cost of a financial crises. We can further show with real data that it is possible to compute the systemic risk contribution of every single financial transaction. We suggest a simple financial insurance scheme that effectively punishes the systemic risk contribution of all transactions. This scheme provides an incentive for market participants to trade financial assets in a way that effectively restructures financial networks, so that contagion events become impossible. With an agent-based model we can demonstrate that this systemic risk-reducing policy practically eliminates systemic risk in a system.

■ New Methods for Understanding Complex Systems, Day 2

YOSHIHIDE WADA



Dr. Yoshihide Wada is a research scientist at the NASA Goddard Institute for Space Studies and Center for Climate Systems Research, Columbia University, USA. He also works for the Department of Physical Geography, Faculty of Geosciences, Utrecht University, the Netherlands and IIASA. He obtained his PhD degree with distinction (Cum Laude) at Utrecht University in October 2013. His completed PhD projects include estimating global water use and water availability by using the global hydrological and water resources model PCR-GLOBWB. His work also includes estimating and projecting global water scarcity, and assessing the sustainability of global groundwater resources. His current research projects include a global assessment of the sustainability of future food production under socioeconomic and climate change, and water scarcity. He is one of the recipients of the Horton (Hydrology) Research Grant by the American Geophysical Union. He has participated in a number of international projects including the European Global Water Scarcity Information Service Project, Inter-Sectoral Impact Model Intercomparison Project and Water Futures and Solutions. He has also participated in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change as a contributing author (Working Group I). Yoshihide Wada (co)authored about 60 publications, 40 of which appeared in international, peer-reviewed journals.

Reducing water scarcity possible by 2050: Linking global assessments to policy dimensions

Water scarcity is not a problem just for the developing world. In California, USA, legislators are currently proposing a \$7.5 billion emergency water plan to their voters; and US federal officials last year warned residents of Arizona and Nevada that they could face cuts in Colorado River water deliveries in 2016.

Irrigation techniques, industrial, and residential habits, combined with climate change, lie at the root of the problem. But despite what appears to be an insurmountable problem, it is possible to turn the situation around and significantly reduce water scarcity in over next 35 years.

We identify strategies in six key areas that we believe can be combined in different ways

in different parts of the world in order to effectively reduce water stress. Water stress occurs in an area where more than 40% of the water from rivers is unavailable because it is already being used – a situation that currently affects about a third of the global population, and may affect as many as half the people in the world by the end of the century if the current pattern of water use continues).

We separate six key strategy areas for reducing water stress into “hard path” measures, involving building more reservoirs and increasing desalination efforts of sea water, and “soft path” measures that focus on reducing water demand rather than increasing water supply, thanks to community-scale efforts and decision-making, combining efficient technology and environmental protection. While there are some economic, cultural, and social factors that may make certain soft-path measures difficult (such as population control), soft-path measures offer the more realistic path forward in terms of reducing water stress by 2050.

■ The Art and Craft of Systems Analysis, Day 2

MARTIN WILLIAMS



Martin Williams is currently a Professor of air quality at King’s College, London, UK. He was until 2014 Chairman of the Executive Body of the UNECE Convention on Long Range Transboundary Air Pollution (CLRTAP) and formerly chair of the CLRTAP EMEP Steering Body. He has authored papers on urban air quality, vehicle emissions, and the links between air quality and climate change including the role of lead author of the policy section of the UNEP Assessment of Short Lived Climate Forcers. Prior to this, he was Head of the Air Quality programme in Defra, the UK Environment Ministry, where he had responsibility for air quality policy, industrial pollution control, and research. At King’s College, his research interests lie in the application of science to policy in air quality and climate change.

Science-policy interface in regard to air-quality and climate negotiations in Europe

■ Devising Integrated Solutions, Day 3



DETLOF VON WINTERFELDT

Detlof von Winterfeldt is a Professor in the Daniel J. Epstein Department of Industrial and Systems Engineering of the Viterbi School of Engineering and a Professor of Public Policy and Management at the Price School of Public Policy at the University of Southern California (USC). From 2009 to 2012 he was on a leave of absence from USC as the Director of IIASA. Concurrently with his term at IIASA, he was a Centennial Professor of Management Science at the London School of Economics and Political Science. In 2003 he co-founded the National Center for Risk and Economic Analysis of Terrorism Events (CREATE), the first university-based center of excellence funded by the US Department of Homeland Security, serving as CREATE’s director until 2008. Throughout his academic career he has been active in teaching, research, university administration, and consulting. He has taught courses in statistics, decision analysis, risk analysis, systems analysis, research design, and behavioral decision research. His research interests are in the foundation and practice of decision and risk analysis as applied to the areas of technology development, environmental risks, natural hazards and terrorism.

■ Howard Raiffa Session (Introduction & chair), Day 2



RONALD R. YAGER

Ronald R. Yager is a professor of information systems and director of the Machine Intelligence Institute at Iona College, USA. He is among the world's most highly cited researchers with over 47,000 citations of his work in Google Scholar. He is editor and chief of the *International Journal of Intelligent Systems* and serves on the editorial boards of numerous other journals. He has published over 500 papers and edited over 30 books in areas related to fuzzy sets, computational intelligence, human behavioral modeling, decision making under uncertainty and the fusion of information. He is the 2016 recipient of the highly prestigious Institute of Electrical and Electronics Engineers (IEEE) Frank Rosenblatt Award and was the recipient of the IEEE Computational Intelligence Society Pioneer award in Fuzzy Systems. He received the special honorary medal of the 50th Anniversary of the Polish Academy of Sciences and the Lifetime Outstanding Achievement Award from International the Fuzzy Systems Association. He has received honorary doctorate degrees, *honoris causa*, from the Azerbaijan Technical University and the State University of Information Technologies, Bulgaria. Yager is a fellow of the IEEE, the New York Academy of Sciences, and the Fuzzy Systems Association. He has served at the National Science Foundation as program director in the Information Sciences program. He was a NASA/Stanford visiting fellow and a research associate at the University of California, Berkeley as well as a lecturer at NATO Advanced Study Institutes. He is a visiting distinguished scientist at King Saud University, Saudi Arabia and an adjunct professor at Aalborg University in Denmark. He received his undergraduate degree from the City College of New York, USA and his PhD from the Polytechnic Institute New York University, USA.

Fuzzy sets methods for constructing multi-criteria decision functions: Mixing words and mathematics

The multiplicity of objectives in most cases of human decision-making requires that we use multi-criteria decision functions in many tasks. This is particularly true in tasks involving large-scale systems. Central to the construction of multi-criteria decision functions is the modeling of the appropriate relationship between the individual component criteria involved in the decision function. In many situations human beings are able to linguistically express the appropriate relationship between the component criteria. Because of its ability to provide a bridge between linguistic expression and mathematical modeling, fuzzy sets technology provides an ideal framework for the construction of multi-criteria decision functions. In this talk we shall describe a number of aggregation operators associated with fuzzy set theory and see how they can be used to formulate multi-criteria decision functions. Particular attention will be paid to formulating multi-criteria functions from linguistically specified user requirements.

■ The Art and Craft of Systems Analysis, Day 2



ANTON ZEILINGER

In the 1970s, Anton Zeilinger started his work on the foundations of quantum mechanics with neutron interferometry (initially together with H. Rauch). Going beyond single-particle phenomena, Zeilinger in the mid-1980s became interested in quantum entanglement, initially with photons, now also with atoms. His most significant contribution are what is today called "GHZ states". These were the first multi-particle states discovered (with Greenberger and Horne) in 1986 and experimentally realized by Zeilinger and his group in 1998. Such multi-particle entanglement states have become essential in fundamental tests of quantum mechanics and in quantum information science, most notably in quantum computation.

Dignitaries and Speakers

Biographies and Abstracts

Since then, Zeilinger has performed many experiments with entangled photons, including quantum teleportation, quantum cryptography, all-optical one-way quantum computation and a number of quantum gates.

The technological progress in all these fields is making new fundamental tests possible. Most recently, Zeilinger became interested in tests of Leggett-type nonlocal theories, in experiments on Kochen-Specker predictions and in fundamental phenomena in quantum entanglement of ultracold atoms.

The most important stages in the career of Anton Zeilinger include the Technical University of Vienna, M.I.T., the Technical University of Munich, the University of Innsbruck, the Collège de France, the University of Vienna and the Austrian Academy of Sciences.

■ **Public Lecture, jointly organized by IIASA and the Austrian Academy of Sciences (Welcome), Day 2**

On 11 November from 18:30 to 20:30, a dedicated poster session will enable conference participants to share a diversity of perspectives on innovative methodologies, applications, and future challenges of systems analysis.

All posters will be displayed for the duration of the conference. The posters are grouped together according to the following themes:

- S1: Requirements for Methodological Advances in Systems Analysis
- S2: Trans-disciplinary Inspiration in Systems Thinking
- S3: The Art and Craft of Systems Analysis
- S4: New Methods for Understanding Complex Systems
- S5: Addressing Diversity in Social Systems
- S6: Devising Integrated Solutions

The maps on page 89 show the location of each of these groups of posters.

Information for Poster Presenters

After registration poster presenters should visit the poster desk (in the registration area of the Laxenburg Conference Center) to check which board number has been allocated to them. Material will be provided to each presenter for fixing posters to the boards. If you require further assistance, please ask staff at the poster desk.

Poster presenters are encouraged to hang their posters as early as possible on the first day to maximize viewing opportunities for fellow participants. Poster presenters are also requested to stand next to their posters during the poster session from 18:30-20:30 on 11 November.

To ensure posters are displayed for as long as possible, please do not remove your poster until after the afternoon coffee break on 13 November. Any posters remaining at the venue after the conference will be taken down by the organizers and kept for one month.

Poster Awards

There are three awards for the best posters, all voted for by conference participants:

- Best poster by an early-career scientist (a PhD student or a researcher with a PhD degree awarded during 2010 to 2015)
- Best poster by a mid-career scientist (a researcher with a PhD degree awarded between 2000 and 2009)
- Best poster overall

The winners of the first prizes in the three categories of poster awards will be invited to return to IIASA for one week to explore opportunities for collaboration with IIASA's researchers, including the coverage of their expenses for travel and accommodation. If the winner is a member of IIASA staff, the award will be replaced with equivalent financial support for attending a scientific conference.

Vote for your best poster by visiting <http://sa2015.iiasa.ac.at/bestposter>

Voting closes at 16:00 on Thursday 12 November.

S1-01 Back to the roots – Accentuate the system approach in energy system modelling

Krook-Riekkola A¹

¹Luleå University of Technology

Energy system models support the evaluation of different energy and climate policies. Working with models assists the understanding of quantitative relationships between different parts of the energy system, across time periods, with various assumptions (Samouilidis, 1980). Still, there will always be aspects that cannot be fully addressed in the model. Evaluating what to include in the model and how to interpret the results are important parts of modeling, that is, the modeling process consists of different steps even if the focus is often on the computable model. This poster aims to discuss how each of those steps can contribute to a more robust and transparent policy analysis. The steps applied are based on operations research, system analysis (Churchman, 1968), and energy system modeling (Tosato, 2009). The first step, in which the studied system is simplified and conceptualized into a model, secures robust results. How the studied system should be represented in the model, will in the end, be a trade-off between what is desired (from a system perspective) and what is available (from a data perspective). The second step is the model itself, in which the algorithms are solved. A structured model and a consistent naming convention are essential for making it possible to trace the results back to the underlying assumptions, for example, for explaining which technologies were chosen, and thereby provide transparency to the analysis. The third step, in which the model results are interpreted and conclusions about the future are made, is the policy analysis itself. A robust analysis needs to also address aspects that the model cannot capture (e.g., interaction with non-energy markets) or that it is not suitable to capture (e.g., ecological footprint, institutional barriers). Step three often results in a better understanding of the “studied system”, and thus new insight into how the system should be represented (Step one). Move the focus from the model development to the modeling process!

S1-02 Implementing sustainability issues in the procurement processes of construction works

Wall J¹, Hofstadler C¹

¹Graz University of Technology

The construction industry has an enormous environmental impact, in terms of resource and energy consumption. Climate change, increasing urbanization, and mobility issues are raising awareness of these challenges, and several strategies for sustainable public procurement have been developed as an emerging policy instrument. However, their implementation is still insufficient and a life cycle consideration is also often missing.

In fact, although minimum requirements are often set to ensure reduced impacts on the environment, a strong focus on economic performance often means the bid with the lowest acquisition cost gets awarded.

From a holistic point of view, it seems that these approaches are just individual solutions and an integrated concept is often missing. Life cycle management in terms of starting with the implementation of sustainability aspects in early project phases and moving along in the various processes of construction project management focusing especially on the process quality could help to push a holistic approach.

In the context of the combination of different goals (life cycle performance vs. lowest acquisition costs) and uncertainties, system analysis is a useful tool to meet the challenges and understand the complex interactions between the different stakeholders and their goals of a successful project delivery.

In our poster contribution a new approach is going to be presented, focusing on aspects of performance-based contracting. Therefore the current procurement process is analyzed and an improved performance-based approach with our understanding of the implementation of sustainability issues is going to be presented.

The contribution is part of an ongoing research project focusing on the implementation of sustainability aspects through the optimization of construction project management.

S1-03 Copula approaches for risk assessment and management

Hochrainer-Stigler S¹, Pflug G¹

¹IIASA

Assessment and management of extreme risk must be carried out differently compared to frequent-event risk. It is especially important to incorporate dependencies among risks. We lay out an approach for modeling dependencies with the use of copulas and how to manage and prevent such risks using a risk-layer approach. We show possible applications of this approach on the local level for Hungary, the regional level for Europe, as well as for systemic risk. We argue that the approach is particularly useful if different changes in risk for different decision makers are expected but need to be incorporated from an integrated systems perspective.

S1-04 Spatial harmonizing of protected areas and renewable energy production

Serrano-León H¹, Kraxner F¹, Leduc S¹

¹IIASA

Climate change mitigation requires transboundary strategies for the expansion of renewable energies (RE) that are compatible with conservation objectives. The diversity of protected areas (PAs) gives room for integration of a sustainable RE development with nature conservation, but the lack of consistency between PAs designations remains a challenge for transboundary planning.

We propose a methodology to harmonize compatibility assumptions between PA and RE potential production. The methodology is based on the International Union for Conservation of Nature's (IUCN) System of Protected Areas in order to be independent from national and regional PA designations. Our approach is based on protection scenarios in order to address the multiple uncertainties regarding compatibility assumptions. Three scenarios were defined as: reduced, medium, and increased protection levels.

The three scenarios assigned different compatibility levels for RE potentials to the different PA classes, varying from no restrictions for RE to total incompatibility. The methodology was tested in the Alpine region for four different RE technologies: bioenergy, wind power, solar PV plants, and hydropower. A spatial analysis was carried out using GIS and the sustainable as well as the economic potential for each RE technology were determined using a techno-economic engineering model for RE systems (BeWhere) developed at IIASA.

The results showed considerable trade-offs between nature protection and the potential for RE production, with significant differences depending on the scenario assumptions. Available area and potential for RE production was notably reduced when higher restrictions were assumed (lower compatibility levels, additional buffer with restrictions to protect the strictest PAs, and exclusion of Natura 2000 sites). This study evidences the importance of clear definition of PA management objectives for strategic planning of sustainable RE expansion.

S1-05 Understanding carbon cycling of terrestrial ecosystems as a fuzzy system

Shvidenko A¹, Schepaschenko D¹, Kraxner F¹, Maksyutov S²

¹IIASA ²National Institute for Environmental Study (NIES)

We outline a methodology of full and verified carbon account of terrestrial ecosystems (FCA) that supposes unbiased assessment of relevant proxy values (here: Net Ecosystem Carbon Budget) and reliable estimation of uncertainties. The FCA is a fuzzy (underspecified) system, of which membership function is inherently stochastic. Thus, any individually used method of FCA is not able to estimate structural uncertainties, that is why usually reported "within method" uncertainties are inevitably partial. Attempting at estimation of "full uncertainties" of the studied system we combine the major methods of terrestrial ecosystems carbon account (landscape-ecosystem method, LEA; process-based models; eddy covariance; and inverse modeling). Assessment of the uncertainties of FCA is provided within each method. Landscape-ecosystem approach (LEA) presents the empirical basis of the FCA in form of an Integrated Land Information System; serves for strict systems designing the account; contains all relevant empirical and semi-empirical data and models. By-pixel parametrization of land cover is provided by utilizing multi-sensor remote sensing data within Geo-Wiki platform and other relevant information based on special optimization algorithms. Major carbon fluxes within the LEA (NPP, HR, disturbances, etc.) are estimated based on fusion of empirical data with process-based elements by sets of regionally distributed models. "Within method" results and uncertainties of the methods examined are harmonized and mutually constrained based on the Bayesian approach. The above methodology have been applied to carbon account of Russian forests for 2000-2010; uncertainties of the FCA for individual years were estimated in limits of $\pm 25\%$, CI 0.9. We discussed strengths and weaknesses of the approach; system requirements to different methods of the FCA, information and research needs; unresolved problems of cognition of fuzzy system; and obtained and potential levels of uncertainties.

S1-06 Robust food-energy-water security management for sustainable socioeconomic and environmental development: Methodological challenges

Zagorodny A¹, Yermoliev Yu^{1,2}, Bogdanov V¹, Heyetz V¹, Knopov P¹, Kostyuchenko Yu¹, Kulik M¹, Libanova E¹, Lylako V¹, Zgurovsky M^{1,3}

¹National Academy of Sciences of Ukraine ²IIASA ³National Technical University of Ukraine

The main goal of this poster is demonstrate the importance of the joint IIASA – National Academy of Sciences of Ukraine project on "Integrated modeling of food, energy and water security management for sustainable social, economic and environmental

developments." Details and methodology of modeling and robust management of inter-relations between food, water, and energy security in Ukraine is discussed and illustrated with examples. In this project an integrated approach to food-water-energy security management requires the development new approaches, accounting for the specifics of systemic "smart risks" dependent on decisions of "intelligent agents," which can lead to potential human-made disasters. The stages of the project are described: integrated modeling of food, energy, and water security, the focus is on issues of food security and agricultural productivity. Methodologies and models which describe the wide variety of interrelated tasks of the project are presented. Different facets of security and robustness concepts representing the diversity of topics and approaches in the project are highlighted.

S1-07 The role of citizen science and crowdsourcing tools in supporting systems analysis at IIASA

Fritz S¹, See L¹, Moorty I¹, McCallum I¹, Perger C¹, Schepaschenko D¹, Lesiv M¹, Shvidenko A¹, Salk C¹, Duerauer M¹, Karner M¹, Sturn T¹, Dresel C¹, Domian D¹, Dunwoody A¹, Kraxner F¹, Obersteiner M¹

¹IIASA

The involvement of citizens in scientific activities from data collection to hypothesis generation is referred to as citizen science. The majority of citizen involvement tends to be on the data collection side, where numerous crowdsourcing platforms have been built to involve citizens in image interpretation, online mapping and other micro-tasks that would not otherwise have been possible. There has been increasing attention directed towards how citizen-contributed data can be used for improved calibration and validation of satellite-derived products, such as land cover, as well as data for modeling purposes.

This poster will provide examples of tools and applications in the area of citizen science and crowdsourcing within the Earth Observation Systems group of the IIASA Ecosystem Services Program. These tools include Geo-Wiki, mobile gaming apps such as Cropland Capture and Picture Pile, and other high-frequency mobile data collection tools. Some of the crowdsourced data have led to improved global maps of cropland, crop-type distributions and forest cover, information which is needed by economic land-use models such as the Global Biosphere Management Model and crop-growth models such as the Environmental Policy Integrated Model. Other data have the potential to help calibrate and validate these models, for example, through information on farm-level crop types and management information. These various activities, and their linkages to systems analysis work at IIASA, will be showcased on the poster.

S1-08 Systems analysis induced dynamic modeling for urban social and ecological sustainability challenges

Das D¹

¹Central University of Technology

Models have been valuable tools for deriving policy interventions for a long time, and will remain so. It is argued that urban social and ecological systems are too complex for provide policy advice to be provided without models. However, it is challenging to ensure that the outcome of the model reflects real-world behavior. Although there are several econometric and statistical models available, it is perceived that Systems Analysis induced System Dynamics (SD) modeling will provide an alternative approach for developing policy interventions to meet the challenges of urban social and ecological systems. Using a case study of a city in India dominated by the information technology industry, this article explores the development and application of a SD model and its veracity for the sustainability of the urban social and ecological systems. An exploratory survey relying on reviewed literature data and the case study was conducted as a precursor to the development of simulation model. Findings suggest that SD modeling principles are able to elicit the complex causal feedback mechanisms among the various attributes of the urban social and ecological systems. It may also be possible to use the model to develop quantifiable simulated scenarios based on the dynamic hypotheses that build on the causal feedback mechanisms. These can then be used for evolving policy interventions to attain sustainability in urban systems. Thus, Systems Analysis induced SD modeling would provide an alternative and robust approach to developing policies to meet the urban social and ecological sustainability challenges.

S2-01 A hardware and software system for geomagnetic data retrieval, exchange, and system analysis**Dobrovolsky MN¹, Soloviev AA¹, Kudin DV², Sidorov RV¹, Grudnev AA¹, Agayan SM¹, Bogoutdinov ShR¹**¹Geophysical Center of the Russian Academy of Sciences ²Gorno-Altaysk State University

A hardware and software system for geomagnetic data retrieval, exchange, and system analysis is being developed by the Geophysical Center of the Russian Academy of Sciences (GC RAS) in the framework of the Federal Target Program "Research and development on priority directions of Scientific and Technological complex of Russia for 2014-2020." It serves as a core of the Russian segment of the international network of the highest standard geomagnetic observations INTERMAGNET. Today geomagnetic data are transmitted from 18 observatories and stations. The particular feature of the system is the automated real-time recognition of anthropogenic and natural magnetic disturbances in incoming data and their classification. The recognition is based on a fuzzy logic approach and a new measure of magnetic activity developed at GC RAS. Another important feature of the system is automated data correction and verification. Along with recognition of anthropogenic disturbances, it facilitates the preparation of the definitive magnetograms from preliminary records, which is normally carried out by data experts manually. Thus, the system implements a system approach to magnetic data analysis. All steps of definitive data preparation are automated and analysis of geomagnetic activity is done based on data from all available observatories.

The collected and adjusted geomagnetic data, as well as recognition results are stored using a relational database management system. Interactive data access is available online.

This research is supported by Grant No. 14.607.21.0058 of the Ministry of Education and Science.

S2-02 Towards systematic evaluation of crop model outputs for global land-use models**Leclère D¹, Azevedo LB¹, Skalský R¹, Balkovic J¹, Havlík P¹, Obersteiner M¹**¹IIASA

Land provides vital socioeconomic resources to the society; however, at the cost of large environmental degradation (Verburg et al., 2013). At the crossroads of these dimensions, agriculture becomes increasingly interconnected to various natural and human systems across various scales. In order to inform the design of policies to navigate land use towards a more sustainable operating space, comprehensive global assessment models are increasingly being used. They rely partly on the loose coupling of biophysical crop models to global economic models, via one-way exchange of output variables (Rosenzweig et al. 2013). Accuracy of variables exchanged strongly influences the outcomes assessed at various scales, and its improvement is likely to require iterative improvements. Yet there has been little effort to document, evaluate and compare these exchange variables across models (Mueller & Robertson et al. 2014).

We here present a novel dataset (the Hypercube) generated by the Environmental Policy Integrated Model (EPIC) crop model and providing the Global Biosphere Management Model (GLOBIOM) with high-resolution information at global scale on the yield, water, and nutrient needs of 16 crops for 15 different combinations of management. We present the dataset and its links to the EPIC and GLOBIOM model, and the rationale for developing a systematic evaluation of the data, before illustrating them with preliminary results.

S2-03 Development of robust land-use decisions in Eastern Europe under technology, climate, and system change: The case of Ukraine**Ermolieva TY¹, Ermoliev YuM¹, Atoyev KL², Golodnikov OM², Gorbachuk VM², Kiriljuk VS², Knopov PS²**¹IIASA ²National Academy of Sciences of Ukraine (GIC)

The states of Eastern Europe (Ukraine and all the adjacent European states Belarus, Hungary, Moldova, Poland, Romania, Slovakia) have experienced technology and system change in land use since the 1990s. Their total land area exceeds the land area of Mexico or Indonesia, their total gross domestic product (in current US dollars) is between those products of Mexico and Indonesia, and their total population is higher than population of the Russian Federation or Japan. Some Eastern European states are in the world top-five producers of corn, rye, oat, triticale, buckwheat, potato, carrot, turnip, apple, gooseberry, raspberry, blueberry, plum, currant, milk (sheep), honey, flax, and other agricultural goods. It is found the agricultural production value of Romania, Slovakia, and Ukraine has higher efficiency (in the terms of water and energy use) than that of Belarus, Moldova, Poland, and Hungary. Therefore, it was expected the regions of Ukraine bordering with Romania and Slovakia are of the highest agricultural productivity. This hypothesis is confirmed by the data of capital and labor use as well as the data of agricultural production value. At the lack of energy resources, in Ukraine water appears to be a critical agricultural production factor. Moreover, the regions of Ukraine experiencing a water deficit happened to be

the most vulnerable ones substantiating the well-known hypothesis on growing role of water resources for sustainable development. Because a water demand depends on the weather conditions and climate changes, the robust land-use decisions are to be developed in order to contribute to the world food security. For instance, Ukraine is transforming from a global breadbasket to a global foodbasket attracting significant investments to food production and export. The strategic investments and operational land-use decisions are based on such modern systemic risk measures as (conditional) value-at-risk, robust variant of mean or maximum loss.

S2-04 System analysis in international development: From concept to application in flood prone communities

Keating A¹, Mechler R¹, Magnuszewski P¹, Liu W¹, Mochizuki J¹

¹IIASA

Disasters pose a growing threat to sustainable development. Disaster risk management efforts have largely failed to arrest key drivers of uncontrolled urbanization and proliferation of assets in high risk areas. Systems analysis provides a unique interpretation of this failure, and a new pathway for remedy. Increasing “buzz” around the concept of disaster “resilience” (fundamentally a systems concept) has opened the door for the application of systems analysis in the complex arena of the social-ecological foundations of risk and development; yet it has been vaguely conceptualized, not offering a concrete approach to operationalization.

We propose a conceptualization of disaster resilience built on system thinking. This conceptualization is centered on wellbeing (healthy system functioning) and explicitly draws attention to system interactions over the long term. We then present a systems analysis conceptual framework for exploring the real-world interconnections between disasters and development. Finally we outline how this framework has been applied with stakeholders in Peru, and present key lessons pertinent for researchers applying systems thinking in complex, socio-ecological governance settings.

S2-05 Modelling the electricity value of Mauritius' sugarcane industrial ecosystem using systems dynamics approach

Mutanga SS¹, Marne dV², Mbohwa C³, Rogner H⁴

¹University of Pretoria ²The Human Science Research Council (HSRC) ³University of Johannesburg ⁴IIASA

Sugar cane, grown widely in African countries, is known to be one of the most productive species in terms of its conversion of solar energy to chemical potential energy. However, the deployment and diffusion of this technology option on large scale basis is hindered by the complexity in bio-electricity generation. The conversion pathways across bio-electricity production involve water, energy, and land-use planning decision and policy making often occurs in separate and disconnected institutional entities. As such the analytical tools used in support of the decision making process are equally fragmented. In addition the supply of feedstock for electricity generation is limited to the crop harvest season. Let alone the supply is threatened by a wide range of factors among which includes declining sugar prices, competing priorities for land and water which hinder growth of this sector. The complexity warrants the need for decision support tools that can be used not only to broaden the understanding of electricity generation but provide ways of enhancing the energy value of sugarcane production systems in an integrated manner. Using Mauritius as an example this study applied Spatial Systems Dynamics Model (SSDM) that provides a platform for multi-disciplinary simulation. The model integrates the spatial complexity in biomass production, socio-technical complexities in electricity production, and environmental implications in terms of emission avoidance. The model provides multiple scenarios of bio-electricity generation projected from 2012 to 2035. The model highlights the significance of good policy interventions required to optimize electricity production, the potential environmental benefits, and technological improvements that are critical for decision-making especially to a small developing island like Mauritius, which depends heavily on imported fossil fuels to meet its energy demand.

S2-06 Integrated analysis of the mobility system and its backing energy system

Georges G¹, Küng L¹, Vögelin P¹, Boulouchos K¹

¹ETHZ-LAV

Energy systems analysis often treats the transport sector as one of many energy consuming. In the case of conventional vehicles that is a valid assumption, since a dedicated infrastructure distributes the fuel virtually independently of electricity and gas networks. However, a wide-spread substitution with renewable carriers, in particular electricity, hydrogen, and synthetic natural gas, would entail a tight coupling. Bottlenecks in one system could adversely affect the other. At the same time, mobility implies at least limited geographical or temporal independence from end energy sources. The resulting flexibility creates exciting opportunities for the systemic integration

of renewables. In all cases, a proper assessment of the future mobility system requires a holistic approach, resolving (1) the demand for mobility services (and secondary services such as in-vehicle heating), (2) the resulting vehicle movements and associated energy conversion process, (3) the energy exchange processes with the backing energy system and (4) the chain of energy conversion, storage, and transmission processes leading up to primary energy sources.

We at the Energy Systems Group at ETHZ-LAV are developing such an integrated simulation approach. Due to our role in the Swiss Competence Centre for Energy Research for Mobility (www.sccer-mobility.ch), efforts currently focus primarily on the mobility sector and its conversion processes. The demand for mobility services is described using statistical data, which is coupled with a detailed technical model of the various vehicles in the fleet and their powertrain technologies. The methodology is showcased with preliminary results from a study on the CO₂ mitigation effects of making passenger cars more lightweight, as well as promoting non-motorized mobility. As an outlook, we show how the geographically and temporally distributed energy demand profiles are integrated in our energy systems model, developed in the context of a project on decentralised power-generation using a swarm of cogeneration units.

S2-07 Path dependence in systems analysis – The outcome of a problem-solving process depends on the path followed

Lahtinen TJ¹, Hämäläinen RP¹

¹Aalto University

Brian Arthur, a IIASA alumni, demonstrated in his seminal paper of 1989 how increasing returns can drive path dependence in technological development and how this can cause an inferior technology to end up in a dominant market position. A similar risk exists in the use of models. The modeling community or problem solving team can become fixed to one approach and only look for refinements in the model that was initially chosen.

We bring path dependence into focus in model-based systems analysis and problem solving. There are usually alternative paths that can be followed in any modeling and problem solving process. Path dependence refers to the impact of the path on the outcomes of the process. The steps of the path include, for example, how the modeling team is formed, the framing and structuring of the problem, the choice of model, the order in which the different parts of the model are specified and solved, and the way in which data or preferences are collected.

We identify and discuss seven possibly interacting origins or drivers of path dependence: systemic origins, learning, procedure, behavior, motivation, uncertainty, and external environment. We provide suggestions on how path dependence can be dealt with.

Awareness of path dependence and its possible consequences is important in systems analysis especially when we are solving complex policy problems related to, for instance, climate change.

S2-08 The statistical mechanics of functionalism

Barbier MRC¹

¹Princeton University

Given that simple systems, such as cellular automata, can exhibit arbitrarily complex structural features, how can one reliably tell when patterns in biological and social systems are accidental rather than functional? Intuitively, the former arise from bulk dynamics while the latter are the product of external selection, their likelihood increasing when the system is under constraint.

I thus propose to define function as a three-place relationship between a system, a task that is achieved by certain states of the system, and a class of equivalence of patterns which occur in these states as different implementations of the function. Weighting each pattern by its probability of occurrence in bulk dynamics, we can construct statistical ensembles for such functional relationships.

This definition underlies an algorithm for detecting and classifying functional module generically, across a wide range of systems including percolation, neural nets, and iterated games.

S2-09 Reindeer husbandry as a social-ecological system in a warming climate

Käyhkö J¹, Horstkotte T¹, Kivinen S¹, Vehmas J¹, Oksanen L¹, Johansen B², Forbes B³

¹University of Turku ²Northern Research Institute NORUT ³Arctic Centre, Finland

The Arctic region is predicted to warm approximately twice as much as the Earth as a whole, on average. This will cause dramatic transformations in the northern ecosystems. Further pressure on the environment are imposed by changes in land use. Natural resources

extraction dissects the tundra with pipelines, open-pit mines and road networks. Simultaneously, our societies convert towards urbanized, highly educated, service-based culture, where populations gaining their livelihood from primary production are ever decreasing. These processes bring about serious challenges to reindeer husbandry. The livelihood is highly dependent on the diverse tundra environment, and deeply rooted in the indigenous Sámi culture. We study various ecosystem interactions in a changing climate and integrate these with reindeer husbandry and the indigenous people dependent on it. Potential climate impacts include transformation of the arctic-alpine tundra into a dense scrubland with conceivable consequences to reindeer husbandry, but also global warming due to decreasing albedo. The social-ecological system of reindeer husbandry includes administrative and ecological processes that do not always correspond in reality. Consequently, management priorities and administration may conflict with local social and ecological processes, resulting in risks of environmental degradation, loss of biodiversity and defeat of traditional livelihoods. On the other hand, by smartly utilizing the migratory reindeer grazing system of the Sámi as a management tool, we could sustain the high-albedo tundra and mitigate global warming while supporting this livelihood against rapid external pressures. We present and discuss in our poster a framework for this Arctic social-ecological system.

S2-10 Reshaping global change science for the 21st century: Young scientists' perspectives

Schinko T¹, Borgomeo E², Dufva M³, Figge L⁴, Schipfer F⁵

¹IIASA ²University of Oxford ³VTT Technical Research Centre of Finland ⁴Maastricht University ⁵Vienna University of Technology

Humanity is facing unprecedented environmental, social, and economic challenges. We ask what the role of the global science community should be in tackling these challenges. Increased awareness of the social context in which science is being produced; acceptance of the importance of controversy; and reflection around normative assumptions underlying research are needed. To help solve humanity's grand challenges scientists need to move towards a transdisciplinary view of science where knowledge emerges from a collaborative environment and where young scientists are trained to work across disciplinary boundaries and engage with policy communities.

S2-11 Solution of evolutionary games via Hamilton-Jacobi-Bellman equations

Krasovskii NA¹, Kryazhimskiy AV¹, Tarasyev AM^{1,3}

¹Urals State Agrarian University ²IIASA ³Institute of Mathematics and Mechanics, Russian Academy of Sciences

This poster is focused on construction of solutions for bimatrix evolutionary games based on methods of the theory of optimal control and generalized solutions of Hamilton-Jacobi-Bellman equations. It is assumed that the evolutionary dynamics describe interactions of agents in large population groups in biological and social models or interactions of investors in financial markets.

Interactions of agents are subject to the dynamic process which provides the possibility to control flows between different types of behavior or investments. It is worth noting that the dynamics of interactions can be interpreted as the system of Kolmogorov's type differential equations. Parameters of the dynamics are not fixed a priori and can be treated as controls constructed either as time programs or on the feedback principle.

Payoff functionals in the evolutionary game of two coalitions are determined by the limit of average matrix gains on an infinite horizon. The notion of a dynamical Nash equilibrium is introduced in the class of control feedbacks within Krasovskii's theory of differential games.

Elements of a dynamical Nash equilibrium are based on guaranteed feedbacks constructed within the framework of the theory of generalized solutions of Hamilton-Jacobi-Bellman equations. The value functions for the series of differential games are constructed analytically and their stability properties are verified using the technique of conjugate derivatives.

The equilibrium trajectories are generated on the basis of positive feedbacks originated by value functions. It is shown that the proposed approach provides new qualitative results for the equilibrium trajectories in evolutionary games and ensures better results for payoff functionals than replicator dynamics in evolutionary games or Nash values in static bimatrix games.

The efficiency of the proposed approach is demonstrated by applications to construction of equilibrium dynamics for agents' interactions in financial markets.

S2-12 Towards a systems approach for sustainable biorefineries

Slegers PM¹, van Boxstel AJB¹

¹Wageningen University

Our society is facing urgent challenges like climate change, population growth, and depletion of resources. Simultaneously, technologies are being developed to mitigate pollution, shift to renewable resources and, progress towards a sustainable economy. One opportunity for a sustainable economy lies in biorefineries. In biorefineries plants are feedstocks for producing both conventional products (food, feed) and new products (chemicals, materials, fuel). As biorefineries develop, they will allow us to replace non-renewable resources for chemical and material production, and at the same time improve the environmental sustainability of production.

In the past the focus of process design was mainly on technical and economic feasibility. Environmental sustainability is typically assessed afterwards, thus leading to small improvement margins. Ideally, sustainability should be included in an early design phase to obtain environmental and economic sustainable biorefinery designs. This integration is an important research challenge.

On this poster we present a systems approach to unravel the connection between sustainability and process design. The first step is assessing the sustainability impact of several biobased cases to determine the most influential design elements and sustainability impacts through a ranking. We start with well-developed biorefineries using sugar beet, potato, and coffee berries. In the second stage these results are compared to those of simplified designs to confirm which design elements and performance indicators are most important. Lastly, the insights are applied to a new algae biorefinery design and the bottlenecks in the design can guide future research. Applying this approach should allow us to integrate sustainability in biorefinery design.

S2-13 Material flow analysis as means to enhance resource governance exemplified by phosphorus

Zoboli O¹, Zessner M¹, Rechberger H¹

¹Vienna University of Technology

The need for enhancing phosphorus (P) governance in Austria as in most other countries is driven by two major objectives: protecting surface waters from eutrophication and ensuring future food and energy security under scenarios of uncertain supply. The first necessary step towards these objectives is the analysis and understanding of the system representing the current situation. In a second step the analysis is extended to performing a historical analysis between 1990 and 2013 and examining in more depth the data quality and its implications in view of decision making and future monitoring.

One of the main objectives of the analysis is to select fields of action aimed at optimizing national P management and to discuss their applicability to the Austrian system, their effectiveness, timeframe and costs. Furthermore, the relative impact of each field of action on the overall national P management is quantified through two proposed indicators, in order to allow for an easier comparison and prioritization.

The selected fields of action are grouped in three categories: 1. Reduction of P demand and consumption; 2. Increase of P recovery and recycling; 3. Reduction of emissions to water bodies. For each selected field of action, the potential improvement with respect to the reference year 2013 is quantified and barriers and opportunities are analyzed. Furthermore, the uncertainty affecting the assessment of the status quo and the estimation of the potential is discussed and priorities for improving data collection schemes are identified.

S2-14 System simulation by SEMoLa

Danuso F¹, Savian F¹, Ginaldi F¹

¹DISA - University of Udine

SEMoLa is a platform for system knowledge integration and modeling that has been under on-going development at University Dipartimento di Scienze Agrarie ed Ambientali, Italy, since 1992. It allows us to create computer models for dynamic systems and to manage different types of information. It is made up of several parts, each dealing with different forms of knowledge in an integrated way: a graphical user interface, a declarative language for modeling, a set of commands with a procedural scripting language, a specific editor with code highlighting (SemEdit), a visual modeling application (SemDraw), a data base management system (SemData), plotting data capabilities (SemPlot), a raster maps management system (SemGrid), a large library of random number generators for uncertainty analysis, support for fuzzy logic expert systems, a neural networks builder, and various statistical tools (basic statistics, multiple and non-linear regression, moving statistics, etc.).

The core part of the platform is the declarative modeling language (SEMoLa; simple, easy to use, modeling language). It relies on system dynamics principles and uses an integrated view to represent dynamic systems through different modeling approaches (state/individual-based, continuous/discrete, deterministic/stochastic) without requiring specific programming skills. SEMoLa is based on an ontology closer to human reasoning rather than computer logic and also constitutes a paradigm for knowledge management.

The SEMoLa platform permits us to simplify the routine tasks of creating, debugging, evaluating, and deploying computer simulation models but also to create user libraries of script commands. It can communicate with other frameworks exchanging—with standard formats—data, modules, and model components.

S2-15 Ergodic to non-ergodic behavior transitions and hysteresis in ecosystem models

Pietsch SA¹, Bednar JE¹

¹IIASA

A widely used concept in natural sciences is the ergodic principle stating that the temporal average state of system equals the average of single states of an ensemble of the system. Originally formulated by Boltzmann to describe the physics of an ideal gas, the ergodic principle was and still is applied in, for example, the assessment of developmental aspects of individuals, but also in the growth series concept of whole ecosystems.

Hysteresis on the other hand describes the observable contrary of the ergodic principle, that is, that the current state of a system strictly depends on the individual temporal development steps, or that individual history is unequivocally important.

This work will provide evidence for ergodic to non-ergodic transitions in the application of biogeochemical ecosystem models using the showcase of Congo Basin rainforests. Using a climate gradient from west to east, ergodic model behavior is shown for a virgin forest refuge, non-ergodic behavior for a current forest savannah mosaic and ergodic behavior again for large open savannahs. Additionally, the occurrence of hysteresis related to the prevailing initial vegetation will be demonstrated, whereby the non-ergodic phase along the climate gradient is shown to be more extensive if rainforest was the original vegetation, as opposed to rainforest establishing on non-forest sites.

The combination of ergodic to non-ergodic transitions—sometimes referred to as catastrophic shifts in ecosystems—will be put into context with the changing distribution patterns of rainforest and savannah over the course of the Holocene.

S3-01 When the well runs dry, where do we go now? Exploring internal migration due to climate stress in Asia and Central and South America

Abel Guy J¹, Muttarak R²

¹Wittgenstein Centre for Demography and Global Human Capital (IIASA, VID/ÖAW and WU) ²IIASA

Whether the changing climate will lead to mass migration remains an unsettled puzzle for migration scholars. To this end, this poster aims to model internal migration flows taking into account socioeconomic, demographic, and environmental drivers. Migration flows and relevant socioeconomic information are obtained from Integrated Public Use Microdata Series for 15 countries in Central and South Americas and 11 countries in Asia over the period 1970-2011. Additionally, precipitation data are employed to identify drought events and rainfall variability which can be environmental driver of migration. Fitting a series of gravity-type spatial interaction models for each country and census year using Poisson regression, we find that people do move out from the areas frequently affected by drought to destinations that are generally more urban and have higher proportions of males. The shorter the distance between origin and destination the higher the migration, especially between contiguous geographical units.

S3-02 Optimal localization of next-generation biofuel production integrated in Swedish forest industry

Wetterlund E¹, Pettersson K², Lundmark R¹, Lundgren J¹

¹Luleå University of Technology ²Chalmers University of Technology

With high availability of forest biomass, Sweden is of considerable interest concerning future large scale production of next-generation biofuels. Large plant sizes, however, increase the required feedstock supply area and put significant demands on the supply chain. Co-location with other industry provides an opportunity for higher total conversion efficiencies, but also puts additional requirements on the locations.

In this study, the geographically explicit optimization model BeWhere Sweden has been used to investigate future production of next-generation biofuels, integrated with existing Swedish forest industry. Focus has been on how different parameters affect biofuel production costs, the choice of technologies and biofuels, and the localization of new biofuel plants. BeWhere Sweden implements a large degree of detail concerning integration potential with existing industry, and considers site-specific conditions for potential host sites.

The results show that the biofuel plant capital cost and the cost of biomass feedstock generally dominate the biofuel cost, but the cost for biomass transportation and biofuel distribution can also have a significant impact. Dimethyl ether produced via black liquor gasification in chemical pulp mills and substitute natural gas produced via solid biomass gasification, integrated with sawmills, dominate the solutions. The choice of technology varies depending on a number of parameters, including criteria for sizing biofuel plants, the electricity price, the biofuel distribution cost and the cost of biomass, and is sensitive to changes in these parameters. Generally, plants with low specific investment costs and/or plants with low specific biomass transportation costs occur most frequently in the solutions. Because these properties often vary significantly among biofuel production facilities at different host industry sites of the same type, the results show the advantage of including site-specific data in this type of model.

S3-03 Power-to-gas and power-to-liquids for managing renewable electricity intermittency in the Alpine Region

Mesfun S¹, Sanchez DL², Leduc S³, Kraxner F³

¹Luleå University of Technology ²University of California-Berkeley ³IIASA

Large-scale deployment of renewable energy sources (RES) can play a central role in reducing CO₂ emissions from energy supply systems, but intermittency from solar and wind technologies present grid integration challenges. High temperature co-electrolysis of steam and CO₂, in the so-called power-to-gas (PtG) and power-to-liquid (PtL) configuration, could provide a path for utilizing the excess intermittent electricity from a power system by converting it into chemical fuels that can be directly utilized in other sectors, such as transportation and heating. The chemical fuels could also be used in the power sector during periods of deficit in supply.

Here, we study the economic and engineering potential of PtG/PtL systems deployment as storage for intermittent renewable electricity and as a source of low-carbon heating and transportation energy among the different energy sectors in the Alpine region, using the BeWhere model, a geographic explicit cost minimization model.

Preliminary results indicate large-scale deployment of the PtG/PtL technologies for producing chemical fuels from excess intermittent electricity is feasible, particularly when incentivized by carbon prices. In addition, large volumes of captured CO₂, as much as 30 Mt CO₂ /

year are utilized in the synthesis of the chemical fuels, providing as much as 23% of liquid transportation fuels. In this context, it can be concluded that PtG/PtL technologies can enable greater integration of RES into the energy supply chain, with application worldwide.

S3-04 Adaptation to increasing risks of forest fires

Khabarov N¹, Krasovskii A¹, Obersteiner M¹, Swart R², Dosio A³, San-Miguel-Ayanz J³, Durrant T³, Camia A³, Migliavacca M⁴

¹IIASA ²Wageningen University and Research Centre ³European Commission – Joint Research Centre ⁴Max Planck Institute for Biogeochemistry

This work presents a quantitative assessment of adaptation options in the context of forest fires in Europe under projected climate change. A standalone fire model (SFM) based on a state-of-the-art, large-scale forest fire modeling algorithm is used to explore fuel removal through prescribed burnings and improved fire suppression as adaptation options. The climate change projections are provided by three climate models reflecting the SRES A2 scenario. The SFM's modeled burned areas for selected test countries in Europe show satisfying agreement with observed data coming from two different sources (European Forest Fire Information System and Global Fire Emissions Database). Our estimation of the potential increase in burned areas in Europe under "no adaptation" scenario is about 200% by 2090 (compared with 2000-2008). The application of prescribed burnings has the potential to keep that increase below 50%. Improvements in fire suppression might reduce this impact even further, for example, boosting the probability of putting out a fire within a day by 10% would result in about a 30% decrease in annual burned areas. By taking more adaptation options into consideration, such as using agricultural fields as fire breaks, behavioral changes, and long-term options, burned areas can be potentially reduced even further.

S3-05 Towards sustainable livestock production systems: Analyzing ecological constraints to grazing intensity

Fetzel T¹, Havlik P², Erb KH¹

¹University of Klagenfurt (SEC) ²IIASA

Increasing food production from cropland and grassland is essential to meet the future food demand of a growing world population without further land-use expansion. It is estimated that until 2050, food production has to increase strongly to meet future food demands. Increasing food production from grasslands in a sustainable way (e.g., by not degrading essential ecosystem services) is important, yet requires a good understanding of the major determinants and constraints of the global livestock production systems and the associated socio-economic and ecological patterns. The spatially explicit analysis of grazing intensity (GI; e.g., the fraction of available Net Primary Production (NPP) that is consumed by grazing animals in a year) using monthly data allow us to analyse the role of seasonality for limits to grazing intensity. Seasonality creates in many regions of the world shortage and surplus periods of NPP, which can (partly) be overcome by social organization, such as the employment of storage technologies or by imports. By comparing the current livestock density to the ecologically maximum density (EMD) determined by biomass availability during shortage periods we show that management has contributed to substantial higher livestock density in many world-regions whereas in others it is still close to the EMD. Our analysis shows to which expense (e.g., length of shortage period to overcome) the increase in livestock-density comes in different world regions and where potential for further biomass extraction exists. This study contributes to an improved understanding of the systemic inter-linkages between GI, seasonal biomass supply, and socioeconomic and ecological trade-offs, and provides essential information for analyzing intensification potentials of grasslands.

S3-06 Systems analysis approach for carbon science economics convergence research for mid-latitude ecotone

Lee WK¹, Moon JY¹, Kraxner F², Shvidenko A²

¹Korea University ²IIASA

The mid-latitude zone can be broadly defined as part of the hemisphere between 30° - 60° latitude. In terms of demographics and level of economic development in the mid-latitude region, approximately 50% of population live in this region, and the scope of research is adjusted to the area particularly between 20°N - 40°N. A number of countries in the mid-latitude region host most of the world's development and poverty related problems (Varis et al., 2011).

According to climatic predictions, ongoing climate change reveals substantial increase in temperature and simultaneous decrease in (basically summer) precipitation across vast continental regions. These tendencies will increase during the 21st century will likely increase the frequency of droughts and water stress of vegetation. Even small changes of climatic indicators (temperature, precipitation) may

provide substantial impacts on ecosystems in this zone since the land cover of a number of countries within the mid-latitude region are comprised mostly of dryland or desert.

In order to tackle the complicated problems arising in the mid-latitudes, a newly initiated project—Carbon Science Economics Convergence Research—will use the systems analysis approach. The crux of this initiative is to examine the social benefits and costs of different strategies for facing climate change while taking into account carbon use. Tackling climate change requires better knowledge of regions and processes, and research findings should consider the benefits, in terms of damages averted, and propose alternative policies, which can be used to design strategies to deal with complex problems coupled with climate change.

S3-07 Adaptive dynamics: Some basic theory and an application

Metz JAJ¹

¹Leiden University & Naturalis Biodiversity Centre, Veolia Environment - Ecole Polytechnique - Museum National d'Histoire Naturelle - Fondation X - IIASA

The theory of structured populations is a mathematical framework for developing and analyzing ecological models that can take account of relatively realistic detail at the level of individual organisms. This framework in turn has given rise to the theory of adaptive dynamics, a versatile framework for dealing with the evolution of the adaptable traits of individuals through repeated mutant substitutions directed by ecologically driven selection. The step from the former to the latter theory is possible thanks to effective procedures for calculating the expected rate of invasion of mutants with altered trait values into a community the dynamics of which has relaxed to an attractor. The mathematical underpinning is through a sequence of limit theorems starting from individual-based stochastic processes and culminating in (i) a differential equation for long-term trait evolution and (ii) various geometrical tools for classifying the evolutionary singular points such as Evolutionarily Stable Strategies, where evolution gets trapped, and branching points, where an initially quasi-monomorphic population starts to diversify.

Traits that have been studied using adaptive dynamics tools are, among others, the virulence of infectious diseases and various other sorts of life-history parameters such as age at maturation. As one example, adaptive dynamics models of respiratory diseases tell that such diseases will evolve towards the upper air passages and hence towards lesser virulence, while at the same time diversifying as a result of limited cross-immunity. Since the upper airways offer the largest scope for disease persistence, they also allow for the largest disease diversification. Moreover, the upward evolution brings with it a tendency for vacating the lower reaches, which leads to the prediction that emerging respiratory diseases will tend to act low and therefore be both unusually virulent and not overly infective.

S3-08 Global high-resolution land-use change projections: A Bayesian multinomial logit downscaling approach incorporating model uncertainty and spatial effects

Krisztin T¹, Havlík P¹, Leclere D¹, Moreau I²

¹IIASA ²UC Louvain

Using econometric models to estimate land-use change has a long tradition in scientific literature. Recent contributions show the importance of including spatial information and of using a multinomial framework to take into account the interdependencies between the land-use classes. Few studies, however, agree on the relevant determinants of land-use change and there are no contributions so far comparing determinants on a global scale. Using multiple 5 arc minute resolution datasets of land-use change between 2000 and 2010 and taking into account the transitions between forest, cropland, grassland and all other land covers, we estimate a Bayesian multinomial logit model, using the efficient Pólya-Gamma sampling procedure introduced by Polson et al. (2013). To identify and measure the determinants of land-use change and the strength of spatial separation, our model implements Bayesian model selection through stochastic search variable selection (SSVS) priors and spatial information via Gaussian Process (GP) priors.

Our results indicate that spatial proximity is of central importance in land-use change, in all regions except the pacific islands. We also show that infrastructure policy, proxied by mean time to market, seems to have a significant impact on deforestation throughout most regions.

In a second step we use aggregate, supra national land-use change results from the partial equilibrium agricultural model GLOBIOM as a framework for projecting our model in ten-year intervals up to 2100 on a spatially explicit scale along multiple shared socioeconomic pathways.

S3-09 Time-periodic and space-cyclic exploitation of renewable resources**Belyakov AO¹, Davydov AA¹, Veliov VM²**¹Lomonosov Moscow State University ²Vienna University of Technology

We consider two models, in which optimal resource extraction can be periodic in time and cyclic in space. The first model is related to an optimal harvesting of an age-structured population with mortality depending on the population size. In contrast to models disregarding the age structure, it is shown that by age or size selective harvesting mode the optimal exploitation may be time periodic, and that is caused by the selectivity of the harvesting. The second model expands the first one to the space dimension and contributes to the optimal cyclic utilization of spatially distributed renewable resources with logistic law of recovery. The resource distributed in space is collected by a single harvester that moves cyclically in the space. Existence of an optimal exploitation mode is proved, as well as necessary optimality conditions for the harvester motion. The numerical algorithm is developed, and economically meaningful features of optimal solutions are revealed.

S3-10 A system dynamics model for flood response**Berariu R¹, Fikar C¹, Gronalt M¹, Hirsch P¹**¹Vienna University of Natural Resources and Life Sciences

To generate a Systems Dynamics (SD)-model, an analysis of the Upper Danube flood was performed to identify crucial factors that influence disaster impacts and response (Berariu et al., 2015). The method consists of a qualitative and a quantitative part. The qualitative CLD illustrates cause-and-effect relationships of flood response. The quantitative Stock-and-Flow-models (SF) represent the quantitative part of SD that allows calculating dynamic changes over time. The stocks indicate the memory of the system and are accumulating dynamic values which can only be influenced by inflow and outflow rates, supplemented by a symbolic valve. Through these valves, inflow and outflow processes are determined by so-called converters, defining rules, laws and other principles for the model input.

The presented model illustrates the duration for conducting flood response measures (installing mobile protection and evacuating the affected population) which strongly depends on the intensity of the event, defined as the height of the water gauge. The model assumes balancing behavior with delay which means that the gap between mobile protection installed and mobile protection needed, requires conducting mobile protection measures. It can be concluded that the most important factor is the speed of the flood wave, determining the critical water level. On the one hand, it influences the starting point of response activities being triggered. On the other, it also determines the point in time when the activities have to be finished. Nevertheless, different results can be observed by assuming varying intensity of the delaying impact by cooperation of the population and of the relief units, mobility of the population, flooded roads and road conditions. Within these variables, the cooperation of the relief units is the most critical, as it directly triggers the duration of the measures.

S3-11 Unlocking the potential of modern bioenergy services in agro-industrial sector in Indonesia: A systems approach**Khatiwada D¹, Silveira S¹, Harahap F¹, Palmén C¹**¹Royal Institute of Technology KTH, Sweden

Indonesia has adopted biofuel and renewable energy policies including mandatory blending targets for biofuels, 5% minimum share of biofuel in the total energy consumption by 2025, and plans for biopower plants. Meeting these ambitious goals has been challenging despite favorable conditions for bioenergy in the country, particularly using palm oil and sugarcane. This study examines sustainability aspects of modern bioenergy systems in agro-industries of Indonesia, considering resource utilization, climate change impact, and fossil fuel substitution. We use a systems approach and multimethods such as lifecycle studies, scenario development, and multidimensional policy analysis. The study finds that the lifecycle emissions of molasses-based ethanol are 29 gCO_{2eq}/MJ, resulting in 67% emissions saving compared to gasoline. However, molasses-ethanol is not sufficient to meet the mandatory targets and thus expansion of cane fields and juice use needs to be considered together with plans for meeting sugar demand. Juice ethanol is needed to meet the ethanol blending targets of 20% (by 2025) using sugarcane obtained from 3.4 Mha land. New developments are also needed to meet the biodiesel blending targets, considering palm oil production practices and different policy frameworks. The mandatory 30% biodiesel blending target (by 2025) would be met from palm oil obtained from 5-7 Mha land after meeting palm oil demand for food production. Improved palm oil yields and coherence sectoral policies, viz. agriculture, climate, and forestry are key for increased biodiesel production. The prospects for biofuels in Indonesia are good but deployment needs to be explored considering resource utilization, coherence of

policy instruments, technological development, and biofuel market creation. This research is part of the program INSISTs (Indonesian-Swedish Initiative for Sustainable Energy Solutions), a joint research and innovation platform established between Sweden and Indonesia.

S3-12 Energy use and emissions of city buses in Brazil – Alternative scenarios for Curitiba

Dreier D¹, Silveira S¹, Khatiwada D¹, V.O. Fonseca K², Nieweglowski R³, Schepanski R³

¹Royal Institute of Technology KTH, Sweden ²Federal University of Technology, Brazil ³Volvo Bus Corporation, Brazil

The transport sector accounts for significant global energy use and emissions due to its traditional dependency on fossil fuels. Climate change, security of energy supply, and increasing mobility demand is mobilizing governments to meet the challenges of sustainable transport. Immediate opportunities to reduce emissions exist through the adoption of new bus technologies, for example, advanced propulsion systems. This paper estimates energy use and emissions during the operation phase (Tank-to-Wheel) of conventional, hybrid-electric, and plug-in hybrid-electric city buses including two-axle, articulated, and bi-articulated chassis types. The systems analysis tool – Advanced Vehicle Simulator (ADVISOR) and a carbon balance method were applied. Seven bus lines and six operation times for each are considered based on real-world GPS data from Curitiba in Brazil. The results show that the hybrid-electric and plug-in hybrid-electric two-axle city buses consume 30% and 71% less energy per distance (MJ/km) compared to the conventional two-axle city bus (i.e. 17.46 MJ/km). Additionally, the energy use per passenger-distance (MJ/pkm) of a conventional bi-articulated city bus amounts to 0.22 MJ/pkm, which is 41% and 24% lower compared to conventional and hybrid-electric two-axle city buses, respectively. This is mainly due to the former's large passenger carrying capacity. The emissions are linearly proportional to the energy use trends following from the carbon balance method, for example, CO₂ emissions for a conventional two-axle city bus amounts to 1299 gCO₂/km. The study shows that advanced propulsion systems with electric drive capabilities and large passenger carrying capacities are beneficial in terms of reducing energy use and emissions of city bus operations in Curitiba. The research is part of a project aimed at sustainable technological solutions for the improvement of urban critical infrastructure in Curitiba, involving Swedish and Brazilian stakeholders.

S3-13 Bayesian networks in decision analysis for complex natural resources problems

Varis O¹

¹Aalto University

This poster documents the development and use of a Bayesian network methodology which has been developed and applied for complex decision analysis problems related to natural resources management. The development work was sparked by a lecture by Howard Raiffa during the IIASA YSSP 30 years ago, and it has incorporated an array of challenging case studies from the Mekong and Senegal River Basins to the fisheries management of the Baltic Sea and climatic change impact assessments. The methodology is a hybrid of classical decision analysis concepts of Raiffa and others, driven by the belief network and influence diagram algorithms of Pearl, Shachter and others, with many original components.

S3-14 Oil prices and their impact on global carbon dioxide emissions

McCullum DM¹, Jewell J¹, Krey V¹, Bazilian M², Fay M², Riahi K^{1,3}

¹IIASA ²World Bank ³Graz University of Technology

Oil prices took a dramatic plunge starting in late 2014 and have remained low ever since. Combined with parallel developments in natural gas supply, this plunge has prompted questions regarding what the “new normal” might mean for energy markets. Will falling oil and gas prices damage the business case for mitigation technologies, such as renewables? Will they stymie incentives to invest in energy efficiency? How do cheaper oil and gas change the outlook for coal and nuclear? Does this spell bad news for efforts to mitigate climate change? While many have weighed in on these questions, no scientific studies have yet addressed them, at least not since the most recent drop in oil prices. A number of economic analyses have studied the very near-term impacts of oil price shocks; meanwhile, scenarios have explored diverging futures where oil prices vary along with multiple other drivers. As yet, however, there has been no explicit and systematic assessment of the longer-term consequences of different oil price futures for global CO₂ emissions. Here we present work using the MESSAGE integrated assessment model, wherein we develop and analyze scenarios with wide-ranging price assumptions that are in line with recent market fluctuations. We find that whether oil prices are stubbornly low or consistently high for decades will have a moderate impact on global emissions and society's ability to mitigate climate change, even though the fuel mix would look quite different in these alternative futures.

S3-15 An efficient mechanism for cross-border support of renewable electricity in the European Union

Busch S^{1,2}, Nakicenovic N^{1,2}, Ortner A², Bedard N³

¹IIASA ²Vienna University of Technology ³University of Zurich

The ability to exchange renewable electricity (RES-e) capacity between EU member states improves the welfare of all member states since potentials and demands for RES-e capacity vary across the EU. This notion is reflected in the promotion of so-called cooperation mechanisms by the European Commission. The existing mechanisms appear, unfortunately, to be insufficient to facilitate an efficient level of trade in capacity across the EU; only a small quantity of energy is expected to be subject to cooperation mechanisms (Klessmann et al. 2010). In order to address these challenges, in this paper we propose a new mechanism for cross-border support of renewable electricity in EU. The guiding idea is that the cross-border mechanism allocates new RES-e generating capacity across EU Member States to where it is most valuable. This can, but need not, coincide with the most cost efficient allocation. The mechanism consists of two main elements. Firstly, a cross-border impact matrix that indicates the spill-over of benefits between member states induced from the power injection of additional RES-e generating capacity. Secondly, an EU wide auction in which member states and generators of RES-e bid prices indicating their willingness to pay for additional RES-e generating capacity. Then for given parameters the auctioneer selects the set of bids that maximizes an EU-wide surplus. We find that the mechanism leads to a decentralized optimization of RES-e support in the EU, by matching high willingness to pay of member states with low cost potentials of RES-e generation, but only if the benefits of RES-e are actually delivered for the member state paying for it. Moreover, the mechanism offers the potential to significantly reduce the barriers of the current cooperation mechanism, such as transaction costs or uncertainty about costs and benefits.

S3-16 Modeling the effects of initial density and copper on competition between *Pseudokirchneriella subcapitata* and *Chlorella vulgaris*

Kim Y¹, Mo HH¹, Lee YS¹, Wee J¹, Cho K¹

¹Korea University

Algal allelopathy is considered a general phenomenon in aquatic environments and it is important to understand the competition between the two algae species. Various factors can affect this phenomenon and lead to complex behavior of algae densities in real environments. In this study, effects of initial density and copper toxicity on competition between *Pseudokirchneriella subcapitata* and *Chlorella vulgaris* were assessed by laboratory experiment and mathematical modeling.

The model was developed to describe the density dynamics of two algae species under six different initial density combinations and 0, 5, and 10 ug/l copper conditions using Powersim software. All experiments were conducted in a 100 mL beaker under 20°C and 16:8 (L:D) condition with periodic observation of cell density. Model predictions were well agreement with observed data, and density dynamics of the two species were associated with both initial density and copper concentration. Results showed that *C. vulgaris* under copper exposure was more sensitive than *P. subcapitata*, and it led to *P. subcapitata* becoming the dominant species, while under control conditions it was not. Furthermore, the copper toxicity was decreased when the initial densities of two algae species were increased. Overall, this model can be used to predict competition between algae under environmental stress and as a tool to understand the complex interactions between the algae species in real environments.

S3-17 Understanding the drivers of urban expansion: Case study of Seville Province

Hewitt R¹, Shchiptsova A², Rovenskaya E^{2,3}

¹Observatorio para una Cultura del Territorio ²IIASA ³Lomonosov Moscow State University

Urban development has accelerated across the globe in recent decades. Much of this development has not been concentrated in cities, but has occurred as dispersed, low-density development outside of major centers but within their area of economic influence, along transport networks, in coastal areas, or close to areas of high natural value. This research focuses on the case study of the province of Seville, Spain, which has experienced notable urban expansion in recent years. We present a systems approach to model dependence between economic development and distribution of urban and non-urban land in this region from data collection to model validation. An extensive search of available indicators of socioeconomic development in this region has been carried out. We apply this data to create a generic statistical model of urban expansion, which links land-use patterns with population density and other indicators of economic growth. The model is tested across the whole Seville region and in its sub-regions to derive drivers of urban expansion in this territory.

S3-18 Delineation of commingled climate and urbanization influences and identification of thresholds in lake-watershed systems: A tentative framework and case studies

Jain S¹, Beyene MT¹

¹University of Maine

In temperate regions, the sustainability of lake-watershed systems is intimately tied to climate, ice phenology, human activities, and biophysical dynamics. We use the state of Maine in the US as our focal region, one with over 5,000 lakes. The recent rise in water temperatures, drop in water quality, and depletion of fish stocks has raised concerns over the future state of these lakes. This study takes the "social-ecological systems" view of Maine lakes with focus on climate-induced shifts in the ice-cover duration. The resulting re-adjustments in the nutrient load assimilation, decrease in lake water quantity, increased radiative heating on phytoplankton productivity, and economic and other losses to the community due to cancellation of winter recreation opportunities have the potential to reshape this vulnerable system. In this poster, we use conceptual models, a delineated social-ecological system, and empirical-statistical analyses to grasp the complexity of this multifaceted system. Prospects for seasonal climate predictability and impact of the future trajectories of El Nino/Southern Oscillation are also discussed.

S3-19 Integrated management of land-use systems under systemic risks and food-(bio)energy-water-environmental security targets: A stochastic global biosphere management model

Ermolieva T¹, Havlík P¹, Ermoliev Y¹, Mosnier A¹, Obersteiner M¹, Leclere D¹, Khabarov N¹, Valin H¹, Reuter W¹

¹IIASA

Interdependencies among land-use systems resemble a complex network connected through demand–supply relations, and disruption of the network may catalyze systemic risks affecting food, energy, water, and environmental security (FEWES) worldwide. This paper describes the conceptual development, expansion, and practical application of a stochastic version of the Global Biosphere Management Model (GLOBIOM), a model that is used to assess competition for land use between agriculture, bioenergy, and forestry at regional and global scales. In the stochastic version of the model, systemic risks of various kinds are explicitly covered and can be analyzed and mitigated in all their interactions. While traditional deterministic scenario analysis produces sets of often contradictory outcomes, stochastic GLOBIOM explicitly derives robust decisions that leave the systems better off, independently of what scenario occurs. Stochastic GLOBIOM is formulated as a stochastic optimization model that is central for evaluating portfolios of robust interdependent decisions: *ex ante* strategic decisions (production allocation, storage capacities) and *ex post* adaptive (demand, trading, storage control) decisions. For example, the model is applied to the case of increased storage facilities, which can be viewed as catastrophe pools to buffer production shortfalls and fulfill regional and global FEWES requirements when extreme events occur. Expected shortfalls and storage capacities have a close relation with Value-at-Risk and Conditional Value-at-Risk risk measures. The Value of Stochastic Solutions is calculated to present the benefits of the stochastic over the deterministic model.

S3-20 Assessing the sensitivity and uncertainty of an NH₃ emission reduction calculator for dairy cattle barns by means of Monte Carlo analysis combined with least square linearization

Mendes LB¹, Demeyer P², Brusselman E², Pieters J²

¹IIASA ²Gent University

With regard to Natura 2000, the Flemish government (Belgium) established the Programmatic Approach to Nitrogen (PAS: acronym in Flemish), with the aim of reducing environmental overload of nitrogen compounds. This approach will have substantial consequences for livestock farms located next to or within special areas of conservation and will likely result in generic measures to reduce ammonia (NH₃) emissions from livestock facilities. An NH₃ emission reduction calculator for dairy cattle systems (AEREC-DC) was adapted based on a mechanistic approach. Reduction coefficients estimated with this tool are used to assess the efficiency of "low NH₃ emission" techniques which can be implemented in Flanders at a later stage. Field measurements will be made in the future to confirm/correct them. Emission reduction techniques combining processes such as floor scraping, flushing, manure acidification, and different types of floor were modeled. The tool comprises 36 input variables, some of which have values that are based on experimental measurements. Nevertheless, reliable information concerning other relevant variables are scarce in the literature. Hence, model sensitivity analysis is imperative. We hypothesize that the ranking of input variables in terms of their effect on the model outcome will change if different uncertainty ranges are assigned to them. Hence, this study was conducted to combine Monte Carlo Analysis associated with Least Square Linearization in order to perform sensitivity and uncertainty analyses on AEREC-DC. The sensitivity analysis was performed by assigning each input variables' probability distribution function (PDF) with a relatively narrow variance (1% of mean value). The uncertainty analysis was carried out by gradually increasing the PDF's variance up to what is considered realistic. The outcomes of this study will help deciding which variables urgently need to be monitored experimentally in order to improve predictions' accuracy.

S4-01 Freshwater ecosystems: From models to applications

Mazzucco R¹, Ficker H^{2,3}, Gassner H^{2,3}, Wanzenboeck J², Nguyen TV⁴, Kim DH¹, Heo M⁴, Chon TS⁴, Dieckmann U¹

¹IIASA ²University of Innsbruck ³Federal Agency for Water Management ⁴Pusan National University

Freshwater ecosystems—lakes and streams—are being endangered by agricultural, urban, and industrial pollution; hydraulic engineering; and overexploitation, which threaten their capacity to provide important services (recreation and supply of food and clean water, among others). Ecological modeling may be employed to estimate impacts and analyze mitigation strategies. Toy models are easy to construct, but applying them to real-world problems is often challenging. Here, we show in two case studies how the connection from model to application can be made. The first study analyzes whether and how the impact of climatic change on a mostly recreational fishery in an Alpine lake can be mitigated, while the second looks at restoring biodiversity after cleaning up pollution in a Korean river system, using aquatic insects, which play an essential functional role in aquatic food-webs and are very sensitive to water quality, as indicators of ecosystem health. These studies highlight the ability of process-based eco-evolutionary models to generate testable hypotheses and contribute solutions to real-world problems.

S4-02 Negative emissions and interactions with other mitigation options: A bottom-up methodology for Indonesia

Kraxner F¹, Leduc S¹, Yowargana P¹, Schepaschenko D¹, Fuss S², Havlik P¹, Mosnier A¹

¹IIASA ²Mercator Research Institute on Global Commons and Climate Change

BECCS (here the combination of forest-based bioenergy with carbon capture and storage) is seen as a promising tool to deliver the large quantities of negative emissions needed to comply with ambitious climate stabilization targets. However, a land-based mitigation option such as large-scale bioenergy production (without CCS) might interfere with other land-based mitigation options popular for their large co-benefits such as reduced emissions from deforestation and degradation (REDD+). We develop a systems approach to identify and quantify possible trade-offs between REDD+ and BECCS with the help of remote sensing and engineering modeling and apply this for illustration to Indonesia. First results indicate that prioritizing REDD+ does imply that there the BECCS potential remains limited. Further research is needed to take into account opportunities where the two options could be deployed synergistically, capitalizing on co-benefits. BECCS and REDD+ must be evaluated from a portfolio perspective, as estimating their potentials independently will not take such opportunities into account.

S4-03 Analysis of close-to-optimal zones in LP decision-support models

Smirnov A¹, Wagner F¹, Rovenskaya E¹

¹IIASA

This project combines the latest insights of different strands of knowledge in order to support environmental policy decision making. Concretely, we use highly efficient computational methods based on mathematical insights of optimization problems to describe all feasible solutions of a linear programming problem that are not optimal but lie “within epsilon” of the optimal solution. These feasible solutions all have some properties in common (not only that they are within a certain cost range, but also that certain functions defined on the solution space (e.g., environmental impact indicators) also lie within certain ranges). In order to identify relevant invariants we project the feasible solutions into two-dimensional planes to make them accessible for direct scrutiny by human eyes. As an example we have applied this method to the GAINS optimization module that is used, inter alia, by European policy makers to design air pollution policies. The method we have developed can be used to efficiently estimate the additional cost for tightening or relaxing environmental constraints. The results generated so far allow us to specifically describe the trade-offs between global and local cost considerations, between different environmental objectives, or between preferences of different regions or countries. The method can also be used to identify directions of the solution spaces that are particularly “flat” with respect to the optimum.

S4-04 Systemic risk management in financial networks with credit default swaps

Leduc MV¹, Sebastian Poledna S^{1,2}, Thurner S^{1,2,3}

¹IIASA ²Medical University of Vienna ³Santa Fe Institute

We study insolvency cascades in an interbank system when banks are allowed to insure their loans with credit default swaps (CDS) sold by other banks. We show that a CDS market can be designed to rewire the network of interbank exposures in such a way that makes it more resilient to insolvency cascades: A regulator can use information about the topology of the interbank network to devise a systemic surcharge that is added to the CDS spread. CDS contracts are thus effectively taxed according to how much they contribute to increasing

systemic risk. We simulate this regulated CDS market using an agent-based model (CRISIS macro-financial model) and we demonstrate that it leads to an interbank system that is more resilient to insolvency cascades.

S4-05 A multi-landform numerical framework for modelling large scale coastal morphodynamics

Andres P¹, Jim WH², David FM², Mark D², Robert JN³

¹Southampton University ²Oxford University ³Auckland University

The work presented in here is part of an ongoing effort aiming to identify the commonalities of existing Large Scale Behavioral simulation models and provide a common quantitative framework able to incorporate the different existing conceptual models. The proposed modeling framework is based on a set of modular objects with simple geometries (i.e., shoreline, profile, ebb-delta volume, etc.) interacting with a gridded sediment accounting data structure. Changes on sediment balance at each grid-cell are derived from changes generated by these simple geometrical objects which embrace multiple cells. A raster grid is used to keep account of volumes of sediments in the required number of fractions in the grid cell. The sediment volumes can then be used to compute approximate elevations.

S4-06 System analysis in recognition of strong earthquake-prone areas

Gvishiani AD¹, Dzeboev BA¹

¹Russian Academy of Sciences

The authors created a new method (FCAZ—Fuzzy Clustering and Zoning) for recognition of highly seismic areas, where epicenters of earthquakes with magnitude $M \geq M_0$ can occur. The magnitude threshold M_0 depends on the seismic activity of a region. The objects of clustering are earthquake epicenters. Suggested approach consists of two steps: clustering of known earthquake epicenters by original DPS (Discrete Perfect Sets) clustering algorithm and obtaining highly seismic zones from clusters of earthquake epicenters by original E2XT algorithm.

The FCAZ system was successfully applied for recognition of strong ($M \geq M_0$) earthquake-prone areas in three seismically hazardous regions: California ($M_0=6,5$), Caucasus ($M_0=5$), and mountain belt of Andes ($M_0=7,75$). Thus, FCAZ demonstrated its efficient applicability for the three significantly different seismically active mountain regions. Their distinctions are emerged in many aspects: geological, geophysical, seismo-tectonic, geomorphological, economical, etc. Nevertheless, not only the results of FCAZ-recognition of potentially highly-seismic zones in California and the Caucasus, but the process of recognition itself, including task definition and approach development, showed their similarity. Also, the quality of results for these three regions turned out to be of the same level.

To sum up, we produced a uniform pattern recognition system for consideration of the earthquake-prone areas problem. In other words, it is a unified systems approach to recognition of strong earthquake-prone areas, which is invariant with respect to magnitude threshold choice ($M_0=5$, $M_0=6,5$, $M_0=7,75$).

It is natural that for any particular problem, defined by choice of M_0 , the FCAZ system has to be tuned using its set of free parameters. This research is supported by Grant No. 14.607.21.0058 of the Ministry of Education and Science of the Russian Federation.

S4-07 Systems intelligence integration: Elucidating the non-computable, incomprehensible, and hidden ill patterns in complex systems behavior

Legaspi R¹, Maruyama H¹

¹The Institute of Statistical Mathematics

We argue that we have yet to fully perceive the complexities of our hyper-connected composite systems since we (a) deny their non-computable aspects, (b) have an abundance of specialized knowledge, but at the same time, a dearth of unified diverse perceptions, and (c) retreat from disentangling an incomprehensible linked system-of-systems only to entangle the components again but with a greater power to elucidate their relationships. As a result, our models of complex systems behavior persistently demonstrate incomplete and fragmented knowledge.

Our solution is an intelligent system with processes that integrate knowledge from heterogeneous sources: (a) big data-centric generalization that can infer hidden system processes and relationships from massive information data points, (b) specialization

engineering that can knowledge-engineer expert and experiential knowledge, and (c) perception computing that can organize varied human perceptions of complex system behaviors. The architecture consists of state-of-the-art knowledge discovery, knowledge integration, and self-improving learning algorithms in artificial intelligence, machine learning, and big data analytics to elucidate the structures and contexts that underlie complex system behaviors.

The integrated intelligence can expose unstated assumptions, reconcile conflicts and inconsistencies, and elucidate ambiguities in system behavior. As new facts are continuously derived with incoming evidence, the intelligent system self-improves its current knowledge. With the synergism of diverse knowledge, the emergence of new intelligence is also possible. The end result is usable intelligence for descriptive, predictive, explorative and prescriptive analyses of complex systems behavior. This intelligence can be used to influence the course of impending, on-going or ensuing system vulnerabilities, destructive perturbations, and critical systemic changes.

S4-08 Transportation planning in complex systems: A case study

Noto G¹, Bereciartua P¹

¹University of Palermo

Urban social and economic development depends to a large extent on the performance of its transportation system (Meyer & Miller, 2000). However, in many areas of the world, urban transportation is getting worse, rather than better, with economic development (Peñalosa, 2005). This negative trend is not necessarily related to lack of investments, but it may depend on the side effects of policies that do not consider the complexity of the environment in which policymakers operate. Such complexity determines the presence of 'wicked' problems in transportation systems. The term 'wicked problems' refers to issues that are hard to define and manage because they often lead to counterintuitive behaviors in terms of time and space when actions are taken to resolve them (Rittel & Weber, 1973).

Traditional planning approaches result inadequate in dealing with wicked issues because they are excessively static in assessing performance at a system level. In fact, they usually focus on demand and supply sub-systems in a short-time perspective and without considering the feedback relationships intervening among them (Zuidgeest & van Maarseveen, 2000). As a result, implemented actions generate wicked behaviors.

The aim of this project is to provide a new approach for planning urban transportation and design effective and sustainable policies which consider the social, technical and financial aspects characterizing mobility within cities. This new planning approach is based on the assumptions of Planning and Control theory and it takes advantage from System Dynamics Modeling.

In order to achieve this aim we developed a case study based on the 'Region Metropolitana Norte', part of the urban area of Buenos Aires. The result is a simulation model that, focusing on the whole transportation system performance, explain us how transportation may develop and influence the territory in the next twenty years.

S4-09 Reconciling information from alternative climate-economic models: A posterior integration approach

Shchiptsova A¹, Kovalevsky D², Rovenskaya E^{1,3}

¹IIASA ²Nansen International Environmental and Remote Sensing Centre ³Lomonosov Moscow State University

Studies of complex systems are non-separable from the analysis of partial and imprecise information received from alternative sources. Due to the high complexity of the underlying processes, researches tend to create an ensemble of multiple models, which describe the studied phenomenon using different modeling approaches and primary assumptions. A system analyst deals then with a set of ensemble outcomes (usually represented by a family of probability distributions), which needs to be integrated into one estimate in order to install the ensemble into the modeling chain or provide support for the informed decision making. This research is focused on the application of the posterior integration method (which was originally developed in IIASA [1] to reconcile stochastic estimates from independent sources) to an ensemble of climate-economic models. Our case-study uses two versions of the stylized model SDEM (Structural Dynamic Economic Model) [2], which generate different outputs (including emissions, CO₂ concentration, temperature, size of economy) under two scenarios: the business-as-usual scenario and mitigation scenario (under carbon tax). We compare original results with results of posterior integration and results of the traditional approach of averaging model outcomes.

[1] Kryazhimskiy, A. (2013) Posterior integration of independent stochastic estimates, IIASA Interim Report IR-13-006.

[2] Kovalevsky, D.V., Hasselmann, K. (2014): Assessing the transition to a low-carbon economy using actor-based system-dynamic models. Proceedings of the 7th International Congress on Environmental Modeling and Software (iEMSs), 15-19 June 2014, San Diego, California, Vol. 4, 1865-1872, URL: http://www.iemss.org/sites/iemss2014/papers/Volume_4_iEMSs2014_pp_1817-2386.pdf.

S4-10 Robust rescaling methods for integrated water, food, and energy security management under systemic risks and uncertainty

Ermoliev Y¹, Ermolieva T¹, Havlík P¹, Mosnier A¹, Obersteiner M¹, Leclere D¹, Fritz S¹, Kyryzyuk S², Kostyuchenko Y²

¹IIASA ²National Academy of Sciences of Ukraine

The aim of this presentation is to discuss robust, non-Bayesian, probabilistic, cross-entropy-based disaggregation (downscaling) techniques. Systems analysis of global change (including climate) processes requires new approaches to integrating and rescaling of models, data, and decision-making procedures between various scales. For example, in the analysis of water security issues, the hydrological models require inputs that are much finer than the resolution of, say, the economic or climatic models generating those inputs. In relation to food security, aggregate national or regional land-use projections derived with global economic land-use planning models give no insights into potentially critical heterogeneities of local trends. Many practical studies analyzing regional developments use cross-entropy minimization as an underlying principle for estimation of local processes. However, the traditional cross-entropy approach relies on a single prior distribution. In reality, we can identify a set of feasible priors. This is relevant, in particular, for land-cover data. Existing global land cover maps (GLC2000, MODIS2000, GLOBCOVER2000) differ in terms of spatially resolved estimates of land use, (e.g., crop, forest, and grass lands). We present novel general approach to achieving downscaling results that are robust with respect to a set of potential prior distributions reflecting non-Bayesian uncertainties, that is, data that are incomplete or not directly observable. The robust downscaling problem is formulated as a probabilistic inverse problem (from aggregate to local data) generally in the form of a non-convex, cross-entropy minimization model. The approach will be illustrated by sequential downscaling aggregate model projections of land-use changes using the Global Biosphere Management Model, with case studies from Africa, Brazil, China, and Ukraine. The approach is being used to harmonize alternative land-cover maps and to develop hybrid maps.

S4-11 The mathematical modeling of uncertainty and risk impact on complex systems instability

Knopov P¹, Atojev K¹, Gorbachuk V¹

¹National Academy of Sciences of Ukraine

Interdependencies of various risks increase the difficulty of identifying the principal cause of injurious effects and make a system already weakened by stress more susceptible to the effects of additional stressors. In the case of cumulative stressors, a system's vulnerability possibilities increases nonlinearly. These nonlinearities lead to an increase of areas of system parameters values that often are characterized by unpredictable behaviors, when small impacts cause essential transformation of a system's security. The rise of uncertainty and unpredictability is often connected with regimes in which a system shows sudden, discontinuous changes or phase transitions as a result of small, continuous changes in variables that influence the system. An advanced modeling method for forecasting of environmental security dynamics was developed. The methodology is based on smooth mappings theory—a mathematical formalism for modeling nonlinear systems behavior. The methodology allows calculation of bifurcation values for system control parameters and estimation of risks for emergencies. The risk of abrupt system transition from one steady state to another state is estimated by deviations of current control parameters from their bifurcation values. The security space transformation is determined by a universal deformation of smooth mappings theory. In the case of two control parameters, characterizing technogenic and ecological factors, the bifurcation curve is computed with support of the universal deformation called cusp. The control parameters are determined with the support of the corresponding indices, usually applied to assess technogenic and environmental security, or contemporary mathematical models, which are used to forecast emergencies on the basis of satellite data.

S4-12 How to increase the accuracy of crowdsourcing campaigns?

Nurmukhametov O¹, Baklanov A^{1,2}, Fritz S², Khachay M^{1,2}, Salk C², See L², Shchepashchenko D²

¹Russian Academy of Sciences ²IIASA

Crowdsourcing is a new approach to performing tasks, with a group of volunteers rather than experts. For example, the Geo-Wiki project [1] aims to improve the global land-cover map by crowdsourcing for image recognition. Though crowdsourcing gives a simple way to perform tasks that are hard to automate, analysis of data received from non-experts is a challenging problem that requires a holistic approach. Here we study in detail the dataset of the Cropland Capture game (part of Geo-Wiki project) to increase the accuracy of campaign's results. Using this analysis, we developed a methodology for a generic type of crowdsourcing campaign similar to the Cropland Capture game. The proposed methodology relies on computer vision and machine learning techniques. Using the Cropland

Capture dataset we showed that our methodology increases agreement between aggregated volunteers' votes and experts' decisions from 77% to 86%.

[1] Fritz, Steffen, et al. "Geo-Wiki. Org: The use of crowdsourcing to improve global land cover." *Remote Sensing* 1.3 (2009): 345-354.

S4-13 Control of diffusion processes in multi-agent networks

Wildemeersch M¹, Chan WHR², Quek TQS³

¹IIASA ²Stanford University ³Singapore University of Technology and Design (SUTD)

Diffusion processes are instrumental in describing the movement of a continuous quantity in a generic network of interacting agents. Here, we present a probabilistic framework for diffusion in networks and propose to classify agent interactions according to two protocols where the total network quantity is conserved or variable. For both protocols, our focus is on asymmetric interactions between agents involving directed graphs. Specifically, we define how the dynamics of conservative and non-conservative networks relate to the weighted in-degree Laplacian and the weighted out-degree Laplacian. We show how network diffusion can be externally manipulated by applying time-varying input functions at individual nodes. The network control and design schemes enable flow modifications that allow the alteration of the dynamic and stationary behavior of the network in conservative and non-conservative networks. The proposed framework is relevant in the context of group coordination, herding behavior, distributed algorithms, and network control.

S4-14 The climate crisis—Why we must limit fossil fuel extraction to stop run-away climate change

Kühne K¹, Schneider E^{1,2}

¹Leave it in the Ground Initiative (LINGO) ²YouthLeader

The poster shows how the extraction and burning of different amounts of fossil fuels would impact the planet—unless we stop it. It builds on a standard way of showing the "dangers" of climate change used by the Intergovernmental Panel on Climate Change commonly known as the "Burning Embers" and expands these with two elements:

- The reserves of fossil fuels that if burnt will lead to a certain rise in atmospheric CO₂ concentrations are charted and show that a 15 year continuation of business as usual in fossil fuel extraction will break the 2° limit.
- Global tipping elements that contribute to a further increase in global temperatures for which amounts of additional warming or CO₂ have been estimated are shown.

This poster is an innovative way of mapping the "operating space" of humanity in the global climate system and its thresholds. It draws more attention to both the critical role of tipping points in the system as well as to the role of fossil fuel extraction which is so far undervalued by climate policy and discourse.

S4-15 Probabilistic spatial and temporal resilience landscapes for the Congo Basin

Pietsch SA¹, Bednar JE¹, Mosnier A¹, Obersteiner M¹

¹IIASA

Recent research by Hirota et al. (2011) introduced the concept of resilience landscapes for tropical forests and savannahs. Basically, the approach statistically relates the probability of current forest/savannah occurrence with the concept of tipping points, at which the ecosystem has no other choice except to switch from on stable state (e.g., forest) to its alternative stable state (e.g., savannah) or vice versa.

This work will use a biogeochemical modelling approach to establish such probabilistic resilience landscapes for the Congo Basin rainforest biome. In a first step, the occurrence of tipping points will be related to climate features like annual precipitation, dry season length, occurrence of startiform non-precipitating cloud cover and the inter-annual variation in precipitation. In the second, spatial resilience landscapes for the Congo Basin will be provided using present climate conditions. Their relation to current forest/savannah distribution will be assessed and evident congruencies and discrepancies will be discussed. In a third step, the concept of temporal resilience landscapes will be developed along the patch-level life cycle dynamics of the Congo Basin rainforest biome. In a final step, the implications of results for ecosystem management decision will be assessed and possible implications on policy and land-use decisions will be presented.

S4-16 Robust strategies for risk-management of rare events**Timonina-Farkas, A¹**¹EPFL, FWF

Nowadays, people, companies and technologies in our fast-developing and changing world are starting to face more and more situations and problems, where they need to take decisions under uncertainty in multi-period environment. The multi-stage stochastic optimization is a well-known mathematical tool for the solution of multi-period decision-making problems under uncertainty. However, (1) the explicit theoretical solution of a multi-stage optimization program may be difficult or even impossible to obtain due to its functional form, as well as (2) usual scenario generation techniques necessary for the numerical solution of the problem may fail due to the lack of the historical data. Moreover, even in case there is enough data to estimate loss/profit distribution function and to generate scenarios based on it, it may appear that every new observation will change the estimated distribution and, hence, will change scenarios and underlying decisions.

Therefore, our goal is to study numerical methods for the solution of the problem by the use of robust approximation techniques, that allow to acquire for the “uncertain uncertainty” and are challenging, important and, very often, irreplaceable solution methods in the multi-stage stochastic optimization.

Scenario approximation methods are applied in a huge variety of areas: starting from financial planning and inventory control, the possible applications include topics of energy production and trading, electricity generation planning, pension fund management, supply chain management etc. In this presentation we focus on the applications in the field of natural hazards risk-management.

S5-01 Diagnosing disaster resilience of communities as complex socioecological systems

Liu W¹, Dugar S, Bhandari D², Keating A¹, Mechler R¹

¹IIASA ²Practical Action Consulting

Global environmental change, growing anthropogenic influence, and increasing globalization of society have made it clear that disaster vulnerability and resilience of communities cannot be understood without knowledge of the broader social-ecological system in which they are embedded. Inspired by iterative multiscale analysis employed by the Resilience Alliance, the related Social-Ecological Systems Framework initially designed by Elinor Ostrom, and the Sustainable Livelihood Framework, we developed a multi-tier framework for conceptualizing communities as multiscale social-ecological systems. We use the framework to diagnose and analyze community resilience to disasters, as a form of disturbance to social-ecological systems, with feedbacks from the local to the global scale. We highlight the cross-scale influences and feedback on communities that exist from lower (e.g., household) to higher (e.g., regional, national) scales. The framework is then applied to real-world community resilience assessment in Nepal and China, to illustrate how key components of socio-ecological systems, including natural hazards, natural and man-made environment, and community capacities can be delineated and analyzed.

S5-02 Improving Ethiopian smallholders' income and food security: An assessment of alternative policy options

Bocqueho G¹, Boere E¹, Mosnier A¹, Havlik P¹

¹IIASA

Smallholder farmers dominate food production, but also represent the largest share of people in developing countries experiencing food insecurity. In Ethiopia, agricultural growth now forms the backbone of the country's long-term plans for economic growth. This study aims to analyze long-term changes to the agricultural sector and its consequences for the evolution of smallholder farmers under various policy scenarios.

A farming typology based on the agro-ecological zone, the dominant activities, and the degree of market integration is established for this purpose. The agro-ecological zone is divided into the rainfall-sufficient and drought prone highland areas and the pastoralist lowlands. Dominant activities are either pure livestock-keeping or a combination of crops and livestock. Market integration is based on the share of agricultural output sold to the market. The resulting typology is extrapolated to all regions of Ethiopia.

The spatially differentiated typology is integrated in an Ethiopia-version of Global Biosphere Management Model (GLOBIOM), a globally-consistent partial equilibrium model representing spatial land-use patterns and accounting for biophysical resource constraints. 19 crops (the standard GLOBIOM crops, teff, coffee and sesame), 4 animal types (cattle, sheep, goats and poultry) and 2 livestock products (milk and meat) are represented in the model. Projections of population and GDP growth per region are used to set up the initial demand for each product and each time step.

Policies aiming to improve food security and reduce poverty are subsequently implemented. These include infrastructure and irrigation extensions as well as the improvement of access to fertilizers. Results show that the distribution of the farming systems changes across space and time under different policy scenarios. Impacts on smallholders' poverty and food security status differ depending on the policy, enabling a spatially explicit assessment of policy options at both the local and national level.

S5-03 BESTGRID process: Going beyond existing practices of stakeholders' participation in electricity transmission projects

Komendantova N¹, Sander A², Schneider T³, Battaglini A⁴

¹IIASA ²ETH-D-USYS ³Potsdam Institute for Climate Impact Research (PIK) ⁴Renewables Grid Initiative (RGI)

The goals of climate change mitigation and energy security policies are key drivers for the EU energy transition towards low-carbon energy generation. Even though alternative technologies, including renewable energy, are well advanced, the current state of electricity grids is one of the bottlenecks for its further deployment. Inhabitants of communities affected by planned infrastructure are protesting against further projects to deploy electricity grids in many European countries. The innovative BESTGRID process brings together organized stakeholders from civil society, academia and the energy sector to understand the nature of concerns about these projects and to test various actions to address the concerns.

The major research questions addressed by this work are:

- What are the main stakeholder concerns about the deployment of electricity transmission grids in Europe?
- What are successful actions to address these concerns?
- Which level of participation can be achieved in electricity transmission infrastructure project siting in Europe?

We address these research questions through a variety of methods, which allow us to gain a systemic look and the holistic understanding of the problem. We analyse five real-world pilot projects which are under planning or construction in Germany (SuedLink and Bertikow-Pasewalk connections), UK (NEMO Link connection) and Belgium (Stevin and Waterloo-Braine l'Alleud connections). We collect empirical data through extensive dialogue with stakeholders, by observation of public and stakeholders information events on-site, by conducting interviews with key stakeholders, and by conducting an on-site survey of all communities where public information events were organized. We mapped participation in each project according to the methodology developed by Arnstein and finally analyzed how concerns about the planned power lines changed before and after actions and policy interventions, which were developed and tested in BESTGRID.

S5-04 Commitment to cooperation and peer punishment: It's evolution

Sasaki T¹, Okada I², Uchida S³, Chen X⁴

¹University of Vienna ²Soka University ³RINRI Institute of Ethics ⁴University of Electronic Science and Technology of China (UESTC)

Theoretical and empirical studies have generally weighed the effect of peer punishment and pool punishment for sanctioning free riders separately. However, these sanctioning mechanisms often pose a puzzling trade-off between efficiency and stability in detecting and punishing free riders. Here we combine the key aspects of these qualitatively different mechanisms in terms of evolutionary game theory. Based on the dilemmatic donation game, we introduce a strategy of commitment to cooperation and peer punishment. To make the commitment credible, we assume that those willing to commit have to make a certain deposit. The deposit will be refunded as long as the committers faithfully cooperate in the donation game and punish free riders and non-committers. It turns out that the deposit-based commitment offers both the efficiency of peer punishment and the stability of pool punishment and that the replicator dynamics lead to transitions of different systems: pool punishment to commitment to peer punishment.

S5-05 Taking differences in institutional quality into account in global forest modelling

Wehkamp J¹, Pietsch SA², Kraxner F², Reuter WH², Fuss S¹, Gusti M², Koch N¹

¹Technical University of Berlin ²IIASA

Forest cover and land-use change models are commonly used for climate scenarios and provide policy advice. The IIASA Global Forest Model (G4M) compares the net present value of agriculture and forestry, and makes a land-use change decision, based on this comparison.

Moving beyond this purely economic rationale, we aimed at understanding in how far integrating differences in environmental institutional quality, could allow improving the representation of forest cover change processes of the model. Through an econometric regression analysis, we identified the most significant out of a larger set of variables on environmental institutional quality and created a composite index. We then implemented the composite index into the model. Its components are: the internalization of environmental norms, the strength of institutions, the ability of the institutions to guarantee macroeconomic stability, the quality of the administration and the efficiency of the bureaucracy.

Through the inclusion of the composite index, the model's residual could be significantly reduced. The results suggest that future research should consider taking differences in environmental institutional quality into account to improve modeling of deforestation processes. Moreover, the implementation of the index into the model allows for the first time to create scenarios for institutional quality and its impact on forest cover.

S5-06 Projection of subnational social heterogeneity in India

Springer M¹, KC S¹

¹IIASA

This study is motivated by two research questions: (1) How does the accounting for socioeconomic heterogeneity, measured by educational attainment, improve population projections for India?, and (2) How will changing patterns in urbanization affect the population projection, depending on the spatial scale (national vs. subnational) considered in the projections?

Projections at national and subnational level can provide essential information for planning and implementing government policies, including the allocation of budget and resources. In a country like India national projections would be too short sighted considering its sheer population size of 1.2 billion inhabitants in 2011.

We aim to show not only the spatial and social heterogeneity of urban and rural India, but also how we implemented this in our subnational projection model. This allows us to show the potential population development of India up to 2050 and how and why the consideration of different spatial levels affect the projection outcome.

S5-07 Filling the cups: Learning about systems through community-based processes

Hager GM¹, Kopainsky B¹, Nyanga PH²

¹University of Bergen ²University of Zambia

Food and farming systems are both complex and dynamic in nature. While smallholder farmers hold vast bodies of practice-based knowledge, rapidly changing and increasingly challenging conditions require them to learn and adapt to change more holistically. The field of System Dynamics and systems thinking offer participatory methods that engage groups of people in learning activities, which are directed at better understanding the interconnected nature and complexities of systems. This study investigates knowledge development of smallholder farmers in Zambia during a systems thinking group intervention. Understanding knowledge development is important to improve the design of learning experiences, especially as they seem to be prerequisite for the effective implementation of adaptive strategies. The results suggest that the use of a system diagram and tangibles, as well as the collaborative construction of the diagram, are crucial components of knowledge change. Furthermore, shared knowledge about system concepts and strategic options is developed through a complex feedback process. During that process, participants converge on an intermediate level of systemic understanding, develop the ability to reason in concise, systemic ways, and critically assess a broad set of strategies to increase food security. However, the results also help clarify the position of systems thinking interventions in the larger scheme of capacity development. It became clear that little is yet known about the process involved in transforming descriptive (language-based, pictorial) knowledge into practice. Hence, future research needs to address this gap between systems knowledge and informed systems action.

S5-08 Synergies and trade-offs between climate mitigation and universal access to clean cooking goals

Cameron C¹, Pachauri S¹, Rao N¹, Riahi K¹, Ummel K¹

¹IIASA

The vast majority of scenarios assessed in the IPCC Fifth Assessment Report fail to sufficiently analyze some of the critical linkages between climate and development. We use an integrated assessment modeling framework—the MESSAGE-Access model—to explore the effects of climate policy on the feasibility and costs of achieving a universal clean cooking goal by 2030 in South Asia. We analyze the interaction between these goals using a wide range of scenarios of mitigation stringency and access policy mechanisms, with particular attention to the distributional effects on different urban/rural and income groups. This analysis is made possible by the application of a novel two-stage optimization framework that combines a household-decision model with a social-choice model.

We find that achieving universal clean cooking by 2030 will require substantial policy efforts and costs even in a world without climate policies, but costs could be up to 44% higher under stringent climate mitigation. Notably, the incremental costs associated with stringent mitigation fall well within the possible range of policy costs from inefficient access support policies.

S5-09 Participatory systems modeling towards integrated spatial planning for functional green infrastructures: A case study from the Baltic Sea Region

Dawson L¹, Elbakidze M²

¹Stockholm University ²Swedish University of Agricultural Sciences

A key factor of success in spatial planning for functional green infrastructure is the ability to coordinate and integrate the various efforts between stakeholders from different sectors at different levels of society. The aim of this study is to identify the barriers and strategies for the integration of a diversity of planning systems and governance frameworks both between and within regions and nations at a variety of scales. We use participatory system dynamics modeling as an enabling tool within an ongoing international transdisciplinary research project focusing on ecological sustainability in the Baltic Sea Region. We conducted four modeling sessions, with 12-27 participants per session representing a broad range of stakeholders from four comparable case study areas (Bergslagen region in Sweden, Braslav Oblast in Belarus, Pskov Oblast in Russia, and Zemgale Planning Region in Latvia) along a broad West-East governance gradient. Knowledge was identified as a key barrier for the planning and management of functional green infrastructure. A causal structure linking knowledge and green infrastructures as landscape outcomes has been investigated through a series of causal loop diagrams. The dynamics identified suggest the primacy of a few core concepts in improving the knowledge base for functional green infrastructure, including social acceptance, availability of funding and resources, and the adequacy of communication strategies. Participatory modeling is effective in structuring constructive dialogues by providing a common language for the investigation of common problems, knowledge-sharing and best practice, and trust-building. However, we also identify a series of methodological challenges for conducting participatory system dynamics for the investigation of broad, paradigmatic social-ecological problems as well as issues encountered when applying the method in a mixed stakeholder, cross-border, multilingual environment.

S5-10 Using systems analysis to forecast labor force participation by age, sex, and educational attainment in Egypt to 2051

Alkitkat H¹, Goujon A²

¹Freelance ²IIASA & VID

Egypt population size has rapidly increased during the past decades to about 87 million inhabitants in 2014. Egypt will only be able to cope with its population-development challenges if it manages to significantly advance its economic development and slow population growth, where an emphasis on human capital formation (education) is likely to be a key factor. The working-age population (15-64) represents about 64% of the total population. However, only 50% of this age-group is engaged in the labor force; and more than 20% is illiterate, this percentage is even higher among women of working age (30%), which explains their low participation in the formal labor force: only 24%.

This paper aims to forecast labor force in Egypt not only by age, sex but also by level of educational attainment, considering education as an important element to enhance labor force participation regardless of its size. Taking into account the continued population growth, the demographic window of opportunity will be flat and long for Egypt, this paper tries to answer the question regarding the ability to "catch it" and benefit from having a large young labor force.

This paper is an extension of the work done by Goujon et al. (2007) on human capital (multistate) projections to 2051 in which we developed projections of the Egyptian population by sex, age, and level of educational attainment (including the provincial level). In the presentation we combine these with future scenarios on the rates of participation of the labor force by age, sex, and level of educational attainment at the national level. A better educated even if growing labor force is likely to be able to lessen some of the expected economic consequences of population growth.

S5-11 Systemic-risk dilemmas emerging from reactive investments

Boza G¹, Dieckmann U²

¹Eötvös-Loránd-University ²IIASA

The stability and prosperity of human societies depend on cooperative exchanges at many levels. While the emergence and stability of such exchanges has been studied extensively, the majority of these investigations have relied on the prisoner's dilemma game. However, cooperative exchanges are typically more complex and involve decisions about continuous investments, instead of simple choices between cooperation and non-cooperation. Our aim here is to understand the factors promoting the emergence and stability

of cooperative exchanges based on continuous investments, performed by individuals with reactive strategies. Through such strategies, agents continuously re-evaluate and adjust their investments according to the gains obtained from an exchange. Such reactivity provides a natural safeguard against exploitation, as it allows agents to fade out unprofitable investments. Here we show that these benefits of reactivity, which are so crucial at the level of agents, exact a high price at the level of the society, by exacerbating systemic risk. In particular, the spread of exuberant investors causes the emergence of boom-bust cycles, characterized by an increase in investment levels followed by a decline. We demonstrate that an optimal level of reactivity can stabilize cooperation while offering safeguards against both exploitation and exuberance. We also study three other fundamental factors: the pace of innovation enhancing strategy diversity, the modularity arising from dividing the collective of agents into smaller groups with sparse interactions between them, and the heterogeneity of such groups structuring social exchanges. We demonstrate how intermediate levels of these additional factors are optimal in terms of stabilizing cooperation while minimizing systemic risk. Our study identifies generally applicable countermeasures against ubiquitous threats to the stability of cooperative exchanges, with a view towards facilitating the design of corresponding future policies.

S5-12 Smarter every day: The deceleration of population ageing in terms of cognition

Bordone V¹, Scherbov S¹, Steiber N¹

¹IIASA

Cognitive decline correlates with age-associated health risks and has been shown to be a good predictor of future morbidity and mortality. Cognitive functioning can therefore be considered an important measure of differential aging across cohorts and population groups. Here, we investigate if and why individuals aged 50+ born into more recent cohorts perform better in terms of cognition than their counterparts of the same age born into earlier cohorts (Flynn effect). Based on two waves of English and German survey data, we show that cognitive test scores of participants aged 50+ in the later wave are higher compared to the participants aged 50+ in the earlier wave. The mean scores in the later wave correspond to the mean scores in the earlier wave obtained by participants who were on average 4-8 years younger. The use of a repeat cross-sectional design overcomes potential bias from retest effects. We show for the first time that although compositional changes of the older population in terms of education partly explain the Flynn effect, the increasing use of modern technology (i.e., computers and mobile phones) in the first decade of the 2000s also contributes considerably to its explanation.

S5-13 REDD-based offsets: Benefit sharing and risks

Krasovskii A¹, Khabarov N¹, Obersteiner M¹

¹IIASA

In this study we apply systems analysis methods to modeling financial instruments supporting the Reduced Emissions from Deforestation and Degradation (REDD) program. We consider a risk-aware forest owner and an electricity producer evaluating the REDD-based offsets with benefit-sharing mechanism under uncertain CO₂ prices. For a range of CO₂ prices and respective risks perceived by the forest owner (seller) and electricity producer (buyer), we apply a model of fair (indifference) pricing. The decision-making process under uncertainty is formalized in the spirit of Howard Raiffa's "Decision analysis" (1968). Parties' risk preferences are reflected by exponential utility functions. The potentially contracted amounts of REDD offsets are analyzed under various risk preferences and for different benefit sharing opportunities and price levels. Our results show that a risk-averse attitude considerably increases the contracted amounts of REDD offsets (compared to risk-neutral case) and, therefore, creates a higher potential for REDD implementation. We demonstrate a possibility of situations, when parties could agree on a certain range of REDD contracts, for example, smaller amounts of REDD offsets are traded for higher prices, and larger amounts for lower prices, but contracting a moderate amount at a moderate price is impossible. Higher benefit-sharing ratios can also increase contracted amounts even in the case of risk-taking electricity producer. Our modeling results highlight two ways to promote higher REDD participation: (i) increasing risk aversion of the energy producers, and (ii) implementing the mechanism of benefit/risk sharing between REDD consumer and supplier.

S5-14 The formation of structured cooperative communities**Sjodin H¹, Brännström Å^{1,2}, Mazzucco R¹, Dieckmann U¹**¹IIASA, ²Umeå University

A society relying upon public goods must avoid a tragedy of the commons; it will otherwise wither owing to the collapse of cooperative enterprises. This long recognized phenomenon has repeatedly caught the attention of thinkers across a variety of fields. Game theory has, through stylized quantitative models, served to unfold core processes governing the nature of cooperation on public goods. While caught between oversimplification and intractability, research is pushing to understand cooperation in complex systems. Large organizational units, such as whole communities, are typically subdivided into a multiple of different localized groups between which individuals may transfer. Although the group structure of such heterogeneous units is known to be important to the success of cooperation, knowledge on how group structures dynamically unfold and develop jointly with cooperative efforts is limited. Public economist Charles Tiebout suggested in 1956 that foot voting as an inter-group migration behavior could constitute a powerful bottom-up solution to the free-rider problem in local governance, as he believed that large communities would self-organize into an optimal type of group-structure. We apply evolutionary game-theory to social group-formation, and find that foot voting spontaneously emerges in large self-organized, public-goods communities. In turn, the emergence of foot voting makes way for cooperation to develop in non-cooperative communities which transform into highly cooperative group-structured societies. As such, the Tiebout hypothesis gets support in evolutionary game theory, and at the same time is revealed as an example of a wider concept, as it builds on a sorting principle that appears inevitable and that may represent a general mechanism for triggering invasion of altruism, potentially at many, and much more basic, levels of social and biological organization.

S5-15 A review of socio-technical energy transition models**Li FGN¹, Trutnevyte E², Strachan N¹**¹UCL Energy Institute ²ETH Zurich

Many existing technical feasibility and modeling studies in the energy field are criticized for their limited treatment of societal actors and socio-political dynamics, poor representation of the co-evolving nature of society and technology, and hence an inability to analyze socio-technical change. At the same time, prominent conceptual frameworks of socio-technical transitions that address these elements are often found to be difficult to operationalize in quantitative energy analyses that meet policy development requirements. However, a new energy modeling paradigm has started to emerge for integrating both quantitative modeling and conceptual socio-technical transitions. This paper provides a taxonomy for this new model category: 'socio-technical energy transition' (STET) models. A review of existing STET models and their applications to the energy supply, buildings and transport sectors is provided. Following this review, the paper reflects on the extent to which these existing quantitative models captured the variety of factors covered in socio-technical transitions theory, highlights the challenges associated with their theoretical and behavioral validation, and proposes future development priorities for STET models.

S5-16 Individual coping versus systemic vulnerability: Theory and applications for Sub-Saharan Africa**Van Wesenbeeck CFA¹, Keyzer MA¹, Sonneveld BGJS¹, Voortman RL¹**¹VU University Amsterdam

Climate change will very likely have a strong impact on the African continent. Of special concern are the effects on food security as coping and adaptation options seem to be limited for parts of the population. This study identifies and localizes vulnerable groups, using food security and health indicators from geo-referenced household surveys. Next, we characterize these vulnerable groups in terms of agro-ecological and socio-economic data, including mechanisms to cope with adverse shocks. For this analysis, we use innovative methods of maximum likelihood prediction for datasets with a large number of integer-valued variables. For west Africa, we find that vulnerable groups in areas likely to be affected by climate change have no paid work, no education, and a relatively old head of household. Coping with adverse shocks is predominantly done within the community and by reliance on adult children living outside the household. In east Africa, the vulnerable belong to the poorest wealth quintile, have no education or paid work, and have few coping options as they are not integrated in local communities.

However, local vulnerability analysis is only part of the story, as individuals coping mechanisms include reliance on assistance of family members outside of the household as well as moving out of the affected areas, causing spreading of the initial shock. Hence, the second part of the study focuses on modeling system dynamics. Negative pressure on the household's nutritional status is transmitted to linked households if a lower threshold is violated, reflecting the fact that households will first use their own reserves before using external

copied mechanisms that impact on other households. This is analogous to the domino stone that will remain upright under some pressure, but then falls if a threshold pressure is exceeded. Given the system dynamics, optimal policy responses are identified, including vulnerable groups but also targeting households pivotal in the social system.

S5–17 Acting with systems intelligence—Appreciating the social and behavioral issues is crucial in the successful application of systems analysis

Hämäläinen RP¹, Saarinen E¹

¹Aalto University

In systems thinking and applied systems analysis we use modeling to improve our understanding of systems and to identify better policies. In the past, researchers have typically focused on the modeling aspects only. However, we also need to pay attention to the whole system created by the analysis team including modeling specialists as well as the stakeholders and decision makers. We need to understand that as systems analysts we become embedded in this overall system and need to act intelligently from within this whole. This is the systems intelligence (SI) perspective by which we take into account the behavioral and motivational biases of the people involved as well as the emotional and social processes created. To accomplish change and commitment to decisions the SI way is to look for positive steps and leverage points for all the actors involved. It is not enough to offer the final solution in the form of data only; the system analysis process needs to be a joint problem-solving process engaging all the actors. This is in line with the win-win philosophy of the jointly improving steps in negotiations proposed by Howard Raiffa in his book "The Art and Science of Negotiation". The SI perspective acknowledges that modelers are also subject to behavioral biases in the modeling process. This has not been widely recognized before, but it is now the core theme of the emerging field of behavioral operational research. We describe the SI concept and review the related literature as well as discuss the so far neglected behavioral issues related to modeling and systems analysis For more on SI visit: <http://systemsintelligence.aalto.fi>.

S6-01 Building a portfolio of weather risk transfer contracts: Contrasts with natural catastrophe contracts and implications for reducing risk to the vulnerable

Bodily S¹, Coleman DM²

¹University of Virginia ²Nephila Advisors

Natural catastrophes have increased in frequency and magnitude and weather variability continues to grow. Natural catastrophe risk contracts have served to reduce risk to counterparties, encouraging governments and individuals to invest in economic activities. In some ways weather-risk transfer contracts are a more attractive business than the natural catastrophe risk business. While natural catastrophe risks that are independent of one another can be found, weather risks that are negatively correlated can be identified and combined in an investment portfolio. We use Monte Carlo simulation and systems analysis to compare the two businesses with regard to their portfolio diversification possibilities. The results are that weather-risk transfer contracts can be combined more efficiently into a less risky portfolio. The implications of these findings are that vulnerable groups on the planet can find cheaper avenues to reduce their risk and lower the impact of unfavorable weather.

S6-02 Assessing the impact of sustainable landscape scenarios for Mato Grosso state, Brazil

Iribarrem A¹, Mosnier A¹, Pirker J¹

¹IIASA

In this poster we present a simplified landscape model aimed at characterizing in better detail production systems in Brazil. Special attention is given to its beef production systems, given the opportunity of improving its low productivity. It includes three production cycles: breed, fatten, and complete; three crop-livestock integrated production systems; Forest-livestock integration; and four grassland types: planted, natural, abandoned, degraded. Preliminary scenario results indicate that the land-sparing due to improvement of beef production will not be unlocked without command and control policies that limit the conversion of native forest to pasture. We also show that a failure in establishing a legal reserve quota market, as allowed by Brazil's new forest code, can lead to leakage in the beef production if combined with strict enforcement of the restoration of legal reserve deficits.

S6-03 Integrated multi-scale modeling framework for assessment of land-use related challenges under global change

Havlík P¹, Valin H¹, Mosnier A¹, Forsell N¹, Frank S¹, Leclère D¹, Palazzo A¹, Ermolieva T¹, Gusti M^{1,2}, Balkovic J¹, Skalský R¹, Schmid E³, Herrero M⁴, Kraxner F¹, Obersteiner M¹

¹IIASA ²Lviv Polytechnic National University ³University of Natural Resources and Life Sciences ⁴Commonwealth Scientific and Industrial Research Organization

Land is the cornerstone of many of the sustainability challenges the world is facing. About 800 million people are still undernourished today, mostly in rural areas. Agriculture will need to expand production by 60% by 2050 to satisfy future food demand but is anticipated to be the sector most directly hit by climate change. At the same time, agriculture, forestry, and land-use change are responsible for 25% of global anthropogenic greenhouse gas (GHG) emissions and these sectors are also key to achieving climate stabilization, as they can provide negative emissions through afforestation and bioenergy production with carbon capture and storage. Advanced system analysis tools are required to capture the multiple dimensions of these challenges: the global partial equilibrium model of agricultural and forest sectors, Global Biosphere Management Model, developed at IIASA, represents the state of the art in model linking across sectors, disciplines, and spatial scales. This model integrates information from a 1x1 km grid where the land characteristics and climate are defined, up to 30 regional aggregates where the international trade is represented. Spatially explicit production activities are defined through Leontief production functions representing the input-output relationships of a large set of production systems/ technologies. Crops, grass, livestock, and forest systems are parameterized through biophysical models which capture overall production and environmental impacts such as carbon and nitrogen balances, water use, or GHG emissions. The model can also be used for market foresight, integrated assessment of climate change impacts and adaptation, or for assessment of mitigation options by providing to energy system models, such as Model for Energy Supply Strategy Alternatives and their General Environmental Impact (MESSAGE) at IIASA, economic information on abatement potential through emissions reduction, carbon sequestration and bioenergy production. More specific applications of the model have also been applied at global, regional and even national level, and validated by numerous publications.

S6-04 Energy sector adaptation in response to water scarcity**Fricko O¹, Johnson N¹, Parkinson S¹, Riahi K¹**¹IIASA

Integrated assessment models (IAMs) have largely ignored the impacts of water scarcity on the energy sector and the related implications for climate change mitigation. However, significant water is required in the production of energy, including for thermoelectric power plant cooling, hydropower generation, irrigation for bioenergy, and the extraction and refining of liquid fuels. With a changing climate and expectations of increasing competition for water from the agricultural and municipal sectors, it is unclear whether sufficient water will be available where needed to support water-intensive energy technologies (e.g., thermoelectric generation) in the future. Thus, it is important that water use and water constraints are incorporated into IAMs to better understand energy sector adaptation to water scarcity.

The MESSAGE model has recently been updated with the capability to quantify the water consumption and withdrawal requirements of the energy sector and now includes several cooling technologies for addressing water scarcity. These new capabilities have been used to quantify water consumption, water withdrawal, and thermal pollution associated with pre-existing climate change mitigation scenarios. The current study takes the next step by introducing water constraints into Shared Socioeconomic Pathway (SSP) scenarios to examine whether and how the energy sector can adapt to water scarcity.

This study will provide insight into the following questions related to energy sector adaptation to water scarcity:

- How does the energy sector adapt to water scarcity in different regions?
- What are the costs associated with adaptation to water scarcity?
- How do adaptations to constraints on water withdrawal and consumption differ?
- Is climate mitigation limited under water scarcity (esp. with low deployment of wind/ solar)?
- How important are dry cooling and seawater cooling for addressing water scarcity and climate mitigation?

S6-05 Modelling the spatio-temporal complexity of rural solar electrification in traditional communities of the Amazon**Jara-Alvear J¹, Callo-Concha D¹, Denich M¹**¹University of Bonn (ZEF)

Universal access to electricity has been envisaged to be achieved by 2030 (SE4All). The major challenge is to provide affordable and high quality electricity supply to rural and isolated communities. For the latter, a decentralized rural electrification (DRE) approach has been proposed as an alternative for electric grid extensions. In the Ecuadorian Amazon, DRE has been implemented for more than a decade through solar home systems confronting constraints such as high installation and operational costs, poor or no maintenance and null financial return. On the other hand, DRE benefits for promoting rural development remain largely unaccounted for, leading to questions regarding their overall sustainability and delayed universal access in remote areas. Therefore, this research focuses on the integration of systems-based approaches to study DRE in indigenous communities of the Ecuadorian Amazon, coupling qualitative, quantitative and spatial analyses. First, an investigation of stakeholders dynamics and a qualitative system model of DRE grounded on peoples values and consensus is provided. Based on this result, a system analysis is performed to identify essential system variables, regulatory mechanism and spatio-temporal scales. Second, a quantitative system dynamic models is developed to substantiate the previous hypotheses and simulate system's behavior. And third, a framework to link the quantitative system dynamic model with GIS is presented, in order to upscale system analysis and hence modeling DRE complexity in a spatio-temporal environment. This will facilitate participation and communication for policy and decision making of rural electrification in non-industrialized countries.

S6-06 Energy modelling on the Alpine Bow**Leduc S¹, Kraxner F¹, Serrano León H¹, Garegnani G², Walzer C³**¹IIASA ²EURAC ³FIWI

The Alpine bow has a great potential for renewable energy (RE) development. At the same time, wildlife in Alpine areas is at risk and has to be protected. More of 40% of the Alpine area is covered by protected areas. They vary in definition and level of protection regarding their category, region, and country. Therefore, some of those protected areas may be suited for the development of bioenergy whereas others may be more suited for the development of hydropower. Using a precise classification of those protected areas, and assuming the correct protection level the techno-economic model, spatial explicit, BeWhere, will identify the potential from hydropower, bioenergy,

wind and solar power while balancing the ecosystems services in the Alps.

The model is based on the minimization of the whole supply chain, starting from the collection of the feedstock to the delivery of the final product to the consumers in the Alps and in the major cities outside the Alps. Access to the site is a determinant issue to build a new power plant in the Alps, therefore the model uses a detailed road network for the transport of the feedstock and accessibility, as well as a map of the high voltage power line. The future RE production plants will be installed if the production cost is competitive enough against fossil fuel based power and heat. The model will then provide the optimal locations, numbers, technologies, and capacities for hydropower stations, bioenergy production plants, solar PV fields and wind parks, together with their corresponding costs and emissions.

A series of scenarios will be carried out varying the fossil fuel price, the carbon cost and the level of protection of the environment. For each of the scenarios, the RE potential, production cost, and emission reductions will be assessed. The results will provide key indications to the stakeholders and the policymakers on the consequences of protecting the environment and the development of RE production.

S6-07 New feed sources key to ambitious climate targets

Walsh B¹

¹IIASA

Net carbon sinks capable of avoiding dangerous perturbation of the climate system and preventing ocean acidification have been identified, but they are likely to be limited by resource constraints. Land scarcity already creates tension between food security and bioenergy production, and this competition is likely to intensify as populations and the effects of climate change expand. Despite research into microalgae as a next-generation energy source, the land-sparing consequences of alternative sources of livestock feed have been overlooked. Here we use the FeliX model to show that microalgae as feedstock can free nearly 2 billion hectares of land currently used for pasture and feed crops. Short rotation biomass plantations established on these areas are capable of meeting over 50% of annual primary energy demand, resulting in emissions mitigation from the energy and LULUC sectors totaling 455 ± 126 PgC by 2100. Further emissions reductions from carbon-sequestering technologies can reduce global atmospheric carbon concentrations close to preindustrial levels by the end of the present century. Though previously thought unattainable, carbon sinks and climate change mitigation of this magnitude are well within the bounds of technological feasibility.

S6-08 Defining new global land-use map in 2050 by including environmental flow requirements

Pastor AV¹, Palazzo A¹, Havlik P¹, Kabat P^{1,2}

¹IIASA ²Wageningen University

Allocation of agricultural commodities and water resources is subject to changes in climate, demographics and dietary patterns. The use of integrated assessment modeling frameworks that combine climate, hydrological, crop and economic models anticipate those future changes. Results from previous integrated assessments have almost always neglected water resources or included them only in a broad way. The focus of this study is on how the inclusion of water resources affects future land use and, in particular, how global change will influence repartition of irrigated and rainfed lands at global scale. We used two general circulation model (GCM) simulations of climate change scenario including a radiative forcing of 8.5 W/m^2 (RCP8.5), the socio-economic scenario (SSP2: middle-of-road), and the Variable Monthly Flow (VMF) method to calculate environmental flow requirements (EFRs). Irrigation withdrawals were adjusted to a monthly time-step to account for biophysical water limitations at finer time resolution. Re-allocation of rainfed and irrigated land might be useful information for land-use planners and water managers at an international level. For example, some countries are likely to adopt measures to increase their water use efficiencies (irrigation system, soil and water conservation practices) to face water shortages, while others might consider improving their trade policy to avoid food shortage and to protect freshwater ecosystems.

S6-09 Renewable energy production from municipal solid waste to mitigate climate change: A spatially explicit assessment for Malaysia

Tan ST¹, Leduc S², Kraxner F²

¹University Technology Malaysia (UTM) ²IIASA

The utilization of municipal solid waste (MSW) as a renewable resource could overcome waste disposal issues, generate power for fossil fuel displacement, and mitigate CO₂ emissions from landfill. However, the availability of waste feedstock varies with the effectiveness of waste

management while the profitability and the environmental impact are mostly dependent on the conversion technology, plant location, and plant capacity. This study aims to evaluate the complexity of waste-to-energy (WTE) supply chain networks for energy production and the CO₂ mitigation potential through a spatially explicit approach. The Malaysian peninsular is selected as a case study area.

This study adapted the IIASA techno-economic engineering model for optimizing renewable energy systems (BeWhere) and developed a WTE optimization component. The model minimizes the full supply chain cost of WTE, optimizes the capacity and location of WTE production plants, and assesses the energy and by-product potentials. Several scenarios were designed to analyze the impact of energy and carbon mitigation potential of WTE with varying the fossil fuel prices or carbon tax in the supply chain.

The results show that incineration and hydrothermal for power production are the preferred options, primarily because of the low economic investment and the high energy conversion efficiency. Apart from the power as the main product, the system produces biofuel as by-product. It is found that most of the plants are installed in more highly populated cities with large potential for waste biomass, hence reducing logistical costs and emissions from transportation. The preliminary results show that WTE could be substituted for about 9% of the Malaysian power production following a business-as-usual scenario.

The study proved that BeWhere for MSW provides a robust spatial explicit solution for WTE with assessment of the energy production and CO₂ mitigation potential.

S6-10 Systems analysis of economic impact of climate change and extremes: A case of a Canadian prairie mixed farm

Poudel S¹, Kulshreshtha S¹

¹University of Saskatchewan

Agriculture systems represent a complex combination of bio-physical components and economic decisions. The bio-economic farm modeling approach has been widely used to simulate agriculture systems for assessing economic impacts and scenario analysis. This study used a Mixed Farm Model for the economic impact assessment of Climate Change and Extremes (MFM-CCE) that accommodates different farm activities, including interaction and interrelation among the activities and their independent response against biophysical factors. A Canadian Prairie mixed farm that has four major crops and three major beef operations namely cow-calf, backgrounding, and finishing combined with forage activities is simulated as a case to assess the economic impact of climate change and extreme over the entire life cycle of beef cattle. A number of sub-models were linked together. A beef cattle herd simulation model was developed to simulate beef operations and was linked to feed availability and demand. In the model, the farm was assumed to have produced enough crops, hay, and pasture to support the beef feed demand. Pasture demand and supply were linked by pasture requirements and productivity. Beef herd crop demand and on-farm crop supply were linked by formulating least cost linear programming problem. Crop mix for the market was selected by formulating a multiyear linear programming algorithms. Crops and hay productivity were estimated through Food and Agriculture Organization AquaCrop model. All these biological and economic components were linked in a spreadsheet for the whole farm simulation and scenario analysis. Scenarios considered were present normal climate (baseline over 1971-2000), future normal (2040-2070), one year as well as back-to-back multi-year moisture stress (drought) conditions in baseline as well as future climate regimes. Back-to-back multi-year drought is the major concern of prairie farmers under both present and future climate regimes. They not only pose immediate financial loss but also severely impact the farm's output supply potential in the future. The result showed that it takes at least four normal years for the farm to gain its normal output supply potential after multiyear drought events.

S6-11 Inclusion of local water solutions as a way to improve the availability and management of water at the peri-urban area of Oaxaca, Mexico

Mendez-Jaime C¹, Salas-Colunga R², Fenner R¹

¹Cambridge University ²Environmental Consultant

Abstract: The consistent growth of urban areas demands reflection on critical management issues such as water. The scientific literature suggests that large water problems occur as a result of lack of governance rather than physical scarcity (Pahl-Wostl, et al., 2012). It should also be recognized that government policies for water management and governance, particularly in developing countries, have little or no focus on environmental or social impacts (Allen, et al., 2006). In the study of urban areas as a system, it is fundamental to understand the dynamics of the land-use change, population growth and environmental services, because they are the most relevant sources of pressure for water resources.

The aim of this research is to identify potential improvements for the governance and management of water at the peri-urban area of

Oaxaca City, Mexico, by the consideration of local solutions to improve the availability of water at the basin.

The investigation followed the methods suggested by the Leibniz Institute for Regional Development and Structural Planning (the IRS handbook analyzing institutional and political contexts of water resources management projects, Beveridge, R. et al., 2012).

In the metropolitan area of Oaxaca City water challenges are related to loss of water sources, use of the aquifer, and pollution. This is aggravated by fragmented management, over-regulation, and a strong influence of political interests. All this results in unsustainable water patterns.

Farmers in the peri-urban area of Oaxaca City have been constructing small reservoirs, water traps and drainage wells, in collaboration with local NGOs. These works have recovered the water table of the aquifer, which has achieved significant energy and economic savings, mainly related with the pumping of water. The engagement of local actors in the management of water has been successful. One relevant strategy has been to solve local problems at the local level, based on local actors' organizational skills and the implementation of new techniques. These activities and results offer the opportunity to replicate this experience in neighboring areas with similar conditions. In this way the basin as a system could experience improved water availability.

S6-12 Modelling of energy storages and power-to-x-technologies in the energy system model TIMES PanEU

Welsch J¹, Blesl M¹

¹University of Stuttgart (IER)

The share of renewable energy in Germany, which is prescribed in the energy concept of the federal government, leads to an increased need for more flexibility options. The aim of this study is the system analytical evaluation of energy storages and power-to-x-technologies in Germany and the interaction with Europe. The basis is the linear European energy system optimization model TIMES PanEU, in which the energy system of the states of the EU-28 as well as those of Norway and Switzerland is modeled. In TIMES PanEU both energy production and deployment as well as the energy demand are mapped. Through consideration of all sectors the cross-sectoral interactions are taken into account, for example, load shift due to changing electricity demand of application technologies. The aim of optimization is to determine the cost-optimal configuration and deployment strategies of energy storages and power-to-x-technologies under the resultant electricity demand structure. Since a temporal structure based on type days for the modeling of different storage technologies and their interactions due to the representation of a storage as a continuous process is not sufficient, a higher temporal resolution is chosen for Germany. In this context, the methodological advantages and disadvantages of modeling of storages in energy system models are discussed. The challenge is to find an appropriate temporal and spatial structure in relation to the complexity of the topology of a model region. The analysis of energy revolution scenarios show that the integration of increasing amounts of electricity from renewable energy sources can be made in the energy system in Germany until 2025/2035 in particular due to the flexibility options curtailment, changed electricity demand, load shifting and power exchanges. As of 2035 an additional construction of large power storages and power-to-heat is also required. A cost analysis as well as an impact analysis of the factors will be made.

S6-13 Coupling terrestrial and marine biophysical processes with livelihood dynamics for analysis of poverty alleviation in Bangladesh

Lazar AN¹, Payo A¹, Nicholls RJ¹, Hutton C¹, Adams H², Salehin M³, Haque A³, Clarke D⁴, Bricheno L⁴, Fernandes JA⁵, Ahmed A⁶

¹University of Southampton ²University of Exeter ³Bangladesh University of Engineering & Technology ⁴National Oceanography Centre Liverpool ⁵Plymouth Marine Laboratory ⁶International Centre for Diarrhoeal Disease Research

Deltas represent one of the most densely populated areas in the world. This is especially true for the coastal zone of Bangladesh where more than a thousand people live in each square kilometre of land. Livelihoods, food security, and poverty in Bangladesh are strongly dependent on natural resources affected by several factors including climate variability and change, upstream river flow modifications, commercial fish catches in the Bay of Bengal, and engineering interventions such as polderisation. The scarcity of fresh water, saline water intrusion and natural disasters (e.g., river flooding, cyclones, and storm surges) have negative impact on drinking water availability and crop irrigation potential; thus severely affect land use and livelihood opportunities of the coastal population. Hydro-environmental changes can be especially detrimental for the wellbeing of the poorest households that are highly dependent on natural resources.

The ESPA Deltas project aims to holistically examine the interaction between the coupled bio-physical environment and the livelihoods of these poor populations in coastal Bangladesh. Here we describe a new integrated model that allows the long-term analysis of the possible changes in this system by linking projected changes in physical processes (e.g., river flows, nutrients), with productivity (e.g.,

fish, rice), social processes (e.g., access, property rights, migration) and governance/management (e.g., fisheries, agriculture, water, and land-use management). This integrated approach is designed to provide Bangladeshi policy makers with science-based evidence of possible development trajectories within the coastal delta plain over timescales up to 50 years, including the likely robustness of different governance options on natural resource conservation and poverty levels. This poster describes the developed integrated analysis framework.

S6-14 The contribution of energy efficiency measures to air quality and related health effects in China's cement industry

Zhang S¹, Worrell E¹, Crijns-Graus W¹, Krol M¹, de Bruine M¹, Geng G², Wagner F³, Röckmann T¹, Cofala J³

¹Utrecht University ²Beijing Normal University ³IIASA

Actions to reduce the combustion of fossil fuels often decrease greenhouse gas (GHG) emissions as well as air pollutants and hereby bring multiple benefits for improvement of energy efficiency, climate change, and air quality associated with human health benefits. Therefore, air quality and health co-benefits can provide strong additional motivation for improving energy efficiency. In China, the cement industry is the second largest energy consumer and key emitter of CO₂ and air pollutants. It accounts for 7% of total energy consumption in China and 15% of CO₂, 21% of PM, 4% SO₂ and 10% of NO_x of total emissions, respectively. In this study, An integrated approach that comprises a number of different methods and tools within the same platform (i.e., provincial energy conservation supply curves (ECSC), Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) model, GIS, TM5, and Health Impact Assessment) is developed and used to assess the potential of energy savings and emission mitigation of air pollutants, as well as the environmental and health impacts of pollution arising from China's cement industry at the provincial level during the period 2011-2030. The results show significant heterogeneity across provinces in terms of potential energy saving as well as emission mitigation of CO₂ and air pollutants (i.e. PM, SO₂, and NO_x) in the next two decades. In addition, the current commercially available energy efficiency measures would decrease 25% of SO₂, 20% of NO_x, and 5% of PM_{2.5} reducing 0.017‰ (5425 case in 2020 and 7811 case in 2030) of premature deaths (adults ≥ 30 ages). Therefore, it is more cost effective for policymakers to consider both air quality and health impacts together when planning and implementing energy policy than to pay attention to each issue separately.

S6-15 The role of fossil carbon capture and storage in the transformation towards a low-carbon energy system

Krey V¹, McCollum DL¹, Riahi K¹

¹IIASA

Over the past few years, the role of carbon capture and storage (CCS) in limiting global mean temperature increase to 2°C has been explored by a number of model intercomparison projects as well as individual modeling studies. A central conclusion highlighted in the Intergovernmental Panel on Climate Change Fifth Assessment Report is that CCS could be one of the most valuable technology options for keeping the door for the 2°C target open.

The current analysis with the MESSAGE integrated assessment model is part of a study that aimed at developing a CCS road map for China, but many of the insights hold true universally. Based on a set of climate policy scenarios with varying levels of stringency, we systematically vary key parameters relevant for the deployment of fossil CCS technologies in the context of the entire energy system.

The scale of CCS deployment in China depends importantly on future costs of CCS technologies, as well as on costs of its low-carbon competitors. In particular nuclear power can be regarded as a competitor to coal CCS in electricity generation because it is also low in carbon and provides base-load electricity. Beyond the relevance of costs, we find that capture efficiency of fossil CCS technologies as well as the ability to control supply chain emissions of fossil fuels—most notably methane emissions for coal mining or natural gas extraction—are a crucial determinant for their deployment potential. This has important implications for choosing among different CCS technology routes, including post- and pre-combustion and oxyfuel technologies for power plants as they offer different perspectives for increasing capture efficiencies beyond the typically assumed 90%. A key technology and policy insight deriving from this finding is that under stringent climate policy, pushing the technology frontier with respect to CO₂ capture efficiencies may be equally important, or even more important, than reducing the costs of CCS technologies further.

S6-16 Advanced stochastic optimization modeling of the water-energy-food nexus for robust energy and agricultural development: Coal mining industry in Shanxi province, China

Gao J², Sun C², Xiangyang X^{1,2}, Cao G-Y³, Ermoliev Y³, Ermolieva T³, Mosnier A³, Rovenskaya E³

¹Center for Resources and Environmental Policy Research ²China University of Mining and Technology ³IIASA

In this presentation, we discuss a modeling framework able to carry out an integrated systems analysis of interdependent energy-food-water-environmental systems while accounting for the competition to those systems posed by restricted natural resources under inherent uncertainties and systemic risks. The case study focuses on developments of coal industry in water-scarce regions of China. Coal is the main energy source in China responsible for country's energy security. However, coal-based industries consume large quantities of water, which exacerbates the problem of water scarcity. The model accounts for water consumption by various coal mining, processing, and conversion technologies, as well as water and land requirements by different crops and management systems. Uncertain water supply and demand require robust solutions that would ensure demand-production balances and other (environmental, social) constraints in all scenarios. The model derives robust interdependent strategic and adaptive decisions using the "public-private partnership" principle. Strategic long-term decisions comprise the choice of coal-related technologies, land allocation, crop portfolio, and management technologies, while adaptive decisions concern trade and water management. Systemic risks and energy-food-water security considerations are characterized by quantile-based indicators arising due to systemic interdependencies among the systems and decisions of various stakeholders and potential adversaries. Robust solutions provide insights into how to develop and coordinate, in a sustainable way, the complex linkages and trade-offs, at spatial and temporal scales, between energy, agriculture, and water sectors, as well as how to manage potential systemic risks inherent to them. The model explores new coherent energy-food-water-environmental policies accounting for local-global interdependencies induced by national-international trade, as well as self-sufficient local solutions.

S6-17 Transformation to a non-fossil society by 2050—the Swedish case of the Stockholm-Mälär region

Liljenström H¹, Svedin U²

¹Swedish University of agricultural Sciences (SLU) ²Stockholm University (SU)

The Swedish University of Agricultural Sciences (SLU) and Stockholm University (SU) are members of the EU COMPLEX Project (2012-2016) together with 17 other European research institutions, including IIASA. The Swedish research Groups at SLU and SU (involving at SU the Department of Computer and Systems Sciences as well as the Stockholm Resilience Center) are jointly examining the issue of how a European sub-national region, in this case the Stockholm-Mälär region, can be transformed to a non-fossil society by the year of 2050 (This constitutes the wp4 of the EU Project). The charge is to investigate central policy issues related to the transition of this region as well as the institutional framing and stakeholder positions. The work explores both the conditions and mechanisms for the transition as well as decision-support tools for actions at various levels. As the societal change has to take place at several levels in society at the same time (e.g., municipal, county, regional, and national levels) against a European general policy contextual frame, the systems analysis considerations involve multiple-level governance, multiple-actor and stakeholder and multi-sectoral considerations. It also balances qualitative and quantitative systems approaches as well as encompassing a combination of perspectives from natural science, economics, social science, and the humanities as well as technology in a futures systems frame. The work therefore exemplifies systems analysis approaches in several ways and has as its thematic target a key central systems challenge for the future of a sustainable world, that is, transforming our society so climate change at global level can be halted latest by 2050. To meet this challenge regional prototypes of ambitions, plans, and ways to formulate strategies will be of high general interest.

S6-18 Energy systems analysis and scenarios: Impacts of car technology market prospects

Gomez J¹, Jochem P¹, Fichtner W¹

¹Karlsruhe Institute of Technology (KIT)

Long-term energy and climate goals are unlikely to be met without behavioral change and new technology deployment in the passenger transport sector. The objective of this work is to examine the extent to which new car technology may contribute to reducing oil demand and greenhouse gas emissions. As an application of systems analysis to the energy and transport sectors, the methodological approach followed is based on systems thinking and feedback processes, adopting a dynamic and nonlinear perspective. Our work, grounded on model-based scenarios analysis, is conducted by combining two methods: aggregate econometrics and computer simulation using system dynamics. The former is applied to project car ownership levels in key car markets. The simulation model developed includes seven fuel types and nine car technologies: conventional (gasoline, diesel), alternative fuel (flexi-fuel, LPG, natural gas) and electric (hybrid,

plug-in hybrid, battery electric, fuel cell). The model is structured into 8 interrelated modules: population-GDP, car stock, travel demand, production costs, policy, technology choice, energy, and emissions. The time horizon is 2000–2030 and the model is applied to China, France, Germany, India, Japan, US. In the modeling exercise, a set of policy options is examined: emission standards, taxation, fiscal incentives for electric cars and investment in charging infrastructure. The key model output is energy use by type of fuel and lifecycle long-lived greenhouse gas emissions. We conclude that: (1) the market penetration and impacts of electric cars depend on time lags and simulated policies; (2) emission standards for new conventional cars may not be sufficient to meet mitigation goals; (3) boundary expansion to incorporate indirect emissions is a necessary model improvement; and (4) policy coordination in the area of electric cars and clean electricity grid is crucial to achieve climate goals.

S6–19 A dammed future for African rivers? Integrating social and environmental impacts of hydropower dams for sustainable water management

Zarfl C¹, Berlekamp J², Kleinteich J¹, Tockner K^{3,4}

¹Eberhard Karls University Tübingen ²University of Osnabrück ³Leibniz-Institute of Freshwater Ecology and Inland Fisheries Berlin ⁴Free University of Berlin

Rapid human population growth, economic development, and urbanization are increasing energy demand in Africa. However, more than 600 million people still lack electricity access. Anticipated climate change has stimulated the search for renewable electricity sources. Hydropower is one of the most approved technologies, which covers about 80% of all renewable sources. In Africa, however, only 8% of the technologically feasible hydropower potential is currently exploited, yet an unprecedented boom in dam construction will more than double hydropower capacity within the next 10-20 years.

There is an urgent need to integrate the environmental and social impacts of future hydropower dams to support decision making in their construction and operation. Based on spatially explicit global data regarding major future hydropower dams under construction or planned (Zarfl et al., 2015), complex interrelations and adverse impacts on human health and the environment will be investigated. Social effects, for example, will include displacement of humans, but also impacts on food security and (drinking) water quality, which is affected by an increase in toxic cyanobacteria blooms, and an increased spread of water-associated diseases. At the same time, dams and reservoir threaten key biodiversity areas, fragment ecosystems, emit greenhouse gases, and alter flow, sediment, and thermal regimes.

A meta-analysis integrates the available information in combination with model approaches to identify processes, parameters, and topic-specific, spatially explicit hotspots of future dam building. Finally, different scenarios will be tested to identify the most suitable way of constructing hydropower dams in African river basins. The systematic analyses and scenarios on where to build hydropower dams will support prioritization and decision making while advancing the standards for the allocation of water for different users, for the benefit of humans and nature alike.

S6–20 A macro-evolutionary model of the joint dynamics of technology, finance, and energy systems

Safarzynska K¹, van den Bergh J²

¹Warsaw University ²UAB Barcelona

Addressing three persistent problems, namely human-induced environmental change, financial instability, and socioeconomic concerns (inequality and unemployment), has now become an urgent necessity. In particular, a transition to a low-carbon economy is widely recognized as inevitable in view of the challenges posed by peak oil and climate change. In this paper, we propose an agent-based model to improve our understanding of the complex interactions between technological, financial and energy systems and how to guide the economy in a more sustainable direction. The underlying framework describes the coevolution of three populations, namely of heterogeneous consumers, producers and banks, who interact through interconnected networks. In this context, we examine how decisions of different economic agents affect financial stability, the direction of technological change and energy use. We discuss different channels through which systemic risk can spread within and between economic networks. Finally, we employ the proposed model to assess macroeconomic impacts of sustainability policies along three dimensions: environmental effectiveness, financial stability, and socioeconomic consequences. In particular, we examine effects of: an energy tax; an equal distribution of incomes; a reduction in working hours; regulations of bank lending to firms; and minimum reserves requirements.

S6–21 Merging Sustainability Science and Energy Economics' Perspectives to Address the “why” and the “how” in an Integrated Tool—Illustrated with the Example of Biogas from Agricultural Waste in Ecuador

Eguez A¹, Bilke R²

¹CERE–Umeå University ²Ecuadorian Renewable Energy and Energy Efficiency Association

Sustainability challenges associated with energy systems are complex and need an interdisciplinary approach. This work explores the complementarity between selected tools from energy economics and sustainability science by merging them into an integrated tool applied to the case of biogas from agricultural waste in Ecuador. The case focuses on the motivations to promote biogas, its obstacles, and the design of policy instruments. The selected tools to be integrated are: market and non-market valuation from the energy economics perspective; and the driving forces, pressures, state, impact, and responses (DPSIR) framework as well as systems dynamics (SD) from the sustainability science perspective. A literature review of these tools is conducted to highlight the main foundations on which they are grounded. Their essence is then used to create an integrated assessment tool. This tool is used to analyze why biogas from agricultural waste has not been promoted in Ecuador despite its potential and how to promote it. The application of the proposed tool demonstrates that SD can use inputs from the DPSIR framework and from market and non-market valuation. Specifically, the DPSIR framework proves to be a useful step prior to the model building in SD, while economic valuation are key to establish the relationship between stock and flow variables in the SD model. Moreover, SD and DPSIR help understand the root causes and dynamics of problems from a holistic perspective, while market and non-market valuations provide quantitative criterion for decision making. These strengths are complemented in the proposed integrated tool.

S6–22 A commercialization strategy for carbon-negative energy

Sanchez DL¹, Kammen DM¹

¹University of California-Berkeley

Climate change mitigation requires gigawatt-scale deployment of clean energy technologies, including carbon-negative technologies like bioenergy with carbon capture and storage (BECCS) to reduce atmospheric CO₂ concentrations. Currently, there are few deployments of BECCS outside of niche markets, creating uncertainty about commercialization pathways and sustainability at scale. This commentary lays out a research and commercialization roadmap for thermochemical co-conversion of biomass and fossil fuels for carbon-negative energy. The flexibility of thermochemical co-conversion enables a viable transition pathway for firms, utilities and governments to achieve net-negative CO₂ emissions in production of electricity and fuels given increasingly stringent climate policy. Primary research and development (R&D) needs are in large-scale biomass logistics, gasification, gas cleaning, and geologic CO₂ storage. R&D programs, subsidies, and policy that recognize co-conversion processes can support this pathway to commercialization. Risks at commercial scale include competition for land and water, but biomass integration likely decreases lifecycle greenhouse gas emissions over coal.

IIASA and its conference partners wish to acknowledge and thank the various conference committees for their work and dedication in organizing Systems Analysis 2015.

Board of Principals

Pavel Kabat (Director General and CEO, IIASA)

Jennifer Dunne (Vice President for Science, Santa Fe Institute)

Stephen Lansing (Co-Director, Complexity Institute, Nanyang Technological University)

Stephen Robinson (Past President, INFORMS)

Peter Slood (Co-Director, Complexity Institute, Nanyang Technological University)

Scientific Committee

IIASA

Chair: **Pavel Kabat** (Director General and CEO)

Vice-chair: **Elena Rovenskaya** (Program Director, Advanced Systems Analysis Program)

Vice-chair: **Ulf Dieckmann** (Program Director, Evolution & Ecology Program)

Markus Amann (Program Director, Mitigation of Air Pollution & Greenhouse Gases Program)

Daniel Jessie (Postdoctoral Research Scholar, Advanced Systems Analysis Program)

Simon Levin (Distinguished Visiting Fellow)

Wolfgang Lutz (Program Director, World Population Program)

Rupert Mazzucco (Research Scholar, Evolution & Ecology Program)

Keywan Riahi (Program Director, Energy Program)

Karl Sigmund (Senior Research Scholar, Evolution & Ecology Program)

Stefan Thurner (Senior Research Scholar, Advanced Systems Analysis Program)

INFORMS

Andrzej Ruszczyński (Distinguished Professor, Management Science & Information Systems, Rutgers Business School, USA)

Darinka Dentcheva (Professor, Department of Mathematical Sciences, Stevens Institute of Technology, USA)

Santa Fe Institute

Geoffrey West (Distinguished Professor)

Luis Bettencourt (Professor, Complex Systems)

Complexity Institute, Nanyang Technological University

Stephen Lansing (Co-Director)

Peter Slood (Co-Director)

Organizing Committee

Co-chair: **Geoff Clarke** (Senior Science Officer, IIASA)

Co-chair: **Iain Stewart** (Head of Communications, Library, and Media, IIASA)

Tom Kaltenbrunner-Danaher & **Carmen Reznik** (Administrative Assistants, IIASA)

Susie Riley (Head of Finance & Sponsored Research, IIASA)

Angelika Scherzer (Program Assistant, IIASA)

IIASA and its conference partners wish to acknowledge and thank the IIASA staff and external suppliers for their work and dedication in organizing Systems Analysis 2015.

Book of Abstracts

Design and layout (Nina Cabala, IIASA)

Language editing (Daisy Brickhill, IIASA)

Branding (A. Dutta, brandkrafts.com)

Catering (Trabitsch Catering GmbH)

Conference publicity (IIASA CLM Department including: Philippa Brooks, Pavel Kareem Hodorocea, Iain Stewart)

Conference support (IIASA staff including: Marzena Adamczuk, Judit Alberti, Aleks Cofala, Angela Dowds, Margit Hegenbart, Tanja Huber, Carmen Marcos, Romeo Molina, Michaela Rossini, Melanie Wenighofer, Darina Zlatanova)

Display materials (cPoint GmbH, Erste österreichische Fahnenfabrik GmbH, Plakativ Werbetechnik GmbH)

Finance and travel (IIASA FSR Department including: Colin Adair, Martin Gugumuck, Martina Wimmer)

Media relations (Katherine Leitzell, IIASA)

Photography (Matthias Silveri)

Technical support (IIASA ICT Department including: John Joseph Amidei, Norbert Eder, Brent Eichenberger, Joseph Undercoffer & Nuntio Audio Video Solutions GmbH)

Venue (Event Residenzen Niederösterreich)

Visa support (Margit Roth-Ahra, IIASA)

Website (Pavel Kareem Hodorocea, IIASA)

Badges

Systems Analysis 2015 is for registered delegates only. Therefore it is important for security reasons to wear your badge at all times during the conference. If you lose your badge or find a lost badge, please contact a member of the conference staff.

Breaks

Coffee breaks will take place in the morning and afternoon on all three days. Tea and coffee will be served at two coffee and drinks stations (see map on page 89). Welcome coffee will also be served from 08:00 every morning.

Carbon Footprint

IIASA aims to minimize the carbon footprint of Systems Analysis 2015:

- The Institute encourages all delegates travelling to the conference to off-set their carbon emissions.
- IIASA will transport delegates by bus between the conference venues and central Vienna. Further, Vienna's public transport is excellent and provides easy connections between the city, conference venue, and the airport.

Conference Secretariat

The Conference Secretariat is located at the opposite end of the corridor from the theater (see map on page 89). It is open from 08:30 to 18:00 on Wednesday to Friday when staff will be available to assist you and answer your questions.

Secretariat telephone: +43 (0) 2236 807 1060

Feedback

Please let us know what you thought about the conference at sa2015.iiasa.ac.at/feedback

IIASA Displays

There will be two displays focusing on a selection of IIASA highlights since the Institute was founded in 1972:

■ IIASA History and Highlights

The display provides a brief history of the leadership and presents a selection of scientific or policy achievements within IIASA's research areas of Energy & Climate Change, Food & Water, Poverty & Equity, and Drivers of Global Change.

Location: Corridor toward IIASA (see map on page 89)

■ IIASA and its National Member Organizations (NMO)

The display provides brief highlights of the research, capacity building, and decision support activities undertaken by IIASA in collaboration with its NMO countries.

Location: Corridor toward IIASA (see map on page 89)

Information Desks

Location: Next to the registration area, with information available on the following topics.

IIASA Alumni Association: Former IIASA staff are encouraged to join the IIASA Alumni Association to keep in touch with the Institute and former colleagues.

IIASA Capacity Building and Academic Training: Spend an exciting research summer as a PhD student at IIASA, or come and join IIASA as a postdoctoral researcher.

IIASA Donor Center: You will be surprised how great it is to participate in shaping the future of our world with an investment in IIASA.

Posters: Pick up the fixing material for your poster and find out where to hang them up.

IIASA Publications: Browse the latest IIASA publications and sign up to receive free copies of IIASA's magazine *Options* and other publications.

Internet Access

Wireless internet access is available in all areas of the Conference Center Laxenburg
Network: GUEST
Username: sa2015
Password: iiasa

Language and Translation

All presentations and discussion sessions will be in English and translation will not be offered.

Lunch

Lunch will be served in the Oval Room and adjoining rooms at the Conference Center Laxenburg. Please note that conference lunches are for registered participants only and not, unfortunately, for non-registered accompanying guests.

Media

All media-related information will be available at the Conference Secretariat, which is located at the opposite end of the corridor from the theater (see map on page 89). The conference media contact is Katherine Leitzell. If you are a member of the media and would like to schedule interviews with speakers, please contact Katherine on cell phone number +43 (0) 676 83807316 or by email at leitzell@iiasa.ac.at.

Medical Emergencies

For critical or major emergencies dial 144. Otherwise contact the Conference Secretariat for assistance on +43 (0) 2236 807 1060.

Parking

Parking is available directly outside the Conference Center Laxenburg.

Smoking

The conference venue and all evening events are no smoking.

Transportation

For those staying in Vienna, special buses will pick up delegates from Operngasse 4, 1010 Vienna (next to Vienna State Opera) between 7:30 and 7:45 on each day of the conference (see map on page 88). The buses are silver and red with "Elite Tour" on them. Buses will return delegates from outside the Conference Center Laxenburg to Vienna at 20:30 on Wednesday, at 21:00 on Thursday, and at 19:00 on Friday. In addition, there will be buses to and from the Heurigen dinner on Friday evening.

Participants can also travel by bus or taxi to the conference venue, as described below.

By bus:

- In Vienna take the red U1 subway line to Hauptbahnhof Station.
- From Hauptbahnhof follow the bus signs to the exit Bus Terminal which is located on the left-hand side adjacent to the main entrance of the train station.
- At the Bus Terminal (Stand N2) you can catch the #566 bus to Laxenburg (sometimes the bus destination may indicate Eisenstadt).

The bus ticket costs €2.20 one way and departs roughly every 30 minutes. The trip takes 35 minutes. The buses will indicate either Laxenburg or Eisenstadt as their destination, but check with the driver whether the bus you are boarding is going to Laxenburg.

You should get off in Laxenburg at the stop called Franz-Josefs-Platz.

Delegates traveling on from Vienna by air can reach Vienna International Airport easily by train or taxi.

Taxis can easily be ordered through the conference secretariat or your hotel.



Poster Session

Wednesday 11 November from 18:30 to 20:30
At the Conference Center Laxenburg

The dedicated poster session will enable conference participants to scope and share a diversity of perspectives on innovative methodologies, applications, and future challenges of systems analysis. A reception of drinks and food will be available.



Public Lecture

Thursday 12 November from 18:45 to 21:00
At the Conference Center Laxenburg

Jointly organized by IIASA and the Austrian Academy of Sciences (ÖAW), this evening session will feature a public lecture by Robbert Dijkgraaf, Director and Leon Levy Professor at the Institute for Advanced Study in Princeton, USA, followed by a reception of drinks and food.



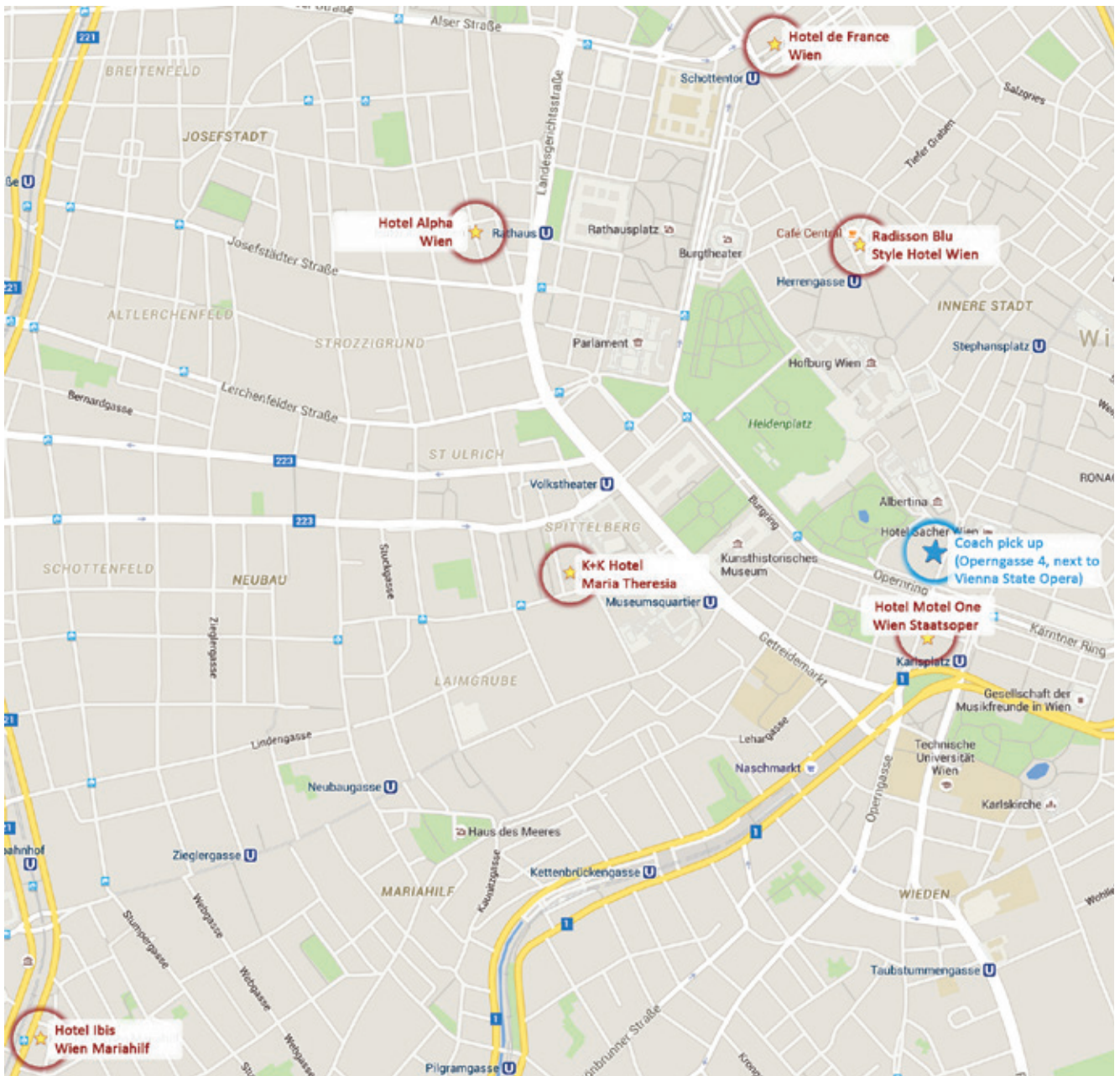
Heurigen Dinner

Friday 13 November from 19:00 to 22:00
At the Klostergasthaus, Thallern

A Heuriger is an East Austrian wine tavern and this informal dinner will round off the three-day conference. Bus transportation will be provided from the Conference Center Laxenburg and then back to central Vienna after the dinner. Please note this dinner costs €45 and many of you will have paid at the time of your online registration for the conference. A sticker on your badge will indicate that you have a place at the dinner. If you did not pre-pay and would like to attend, please contact a member of the conference staff at the conference center.

General Information

Map of Vienna



Hotels

Hotel Ibis Wien Mariahilf
 Mariahilfer Gürtel 22–24, 1060 Vienna
 Telephone: +43 (0)1 599 980
 E-Mail: h0796@accor.com

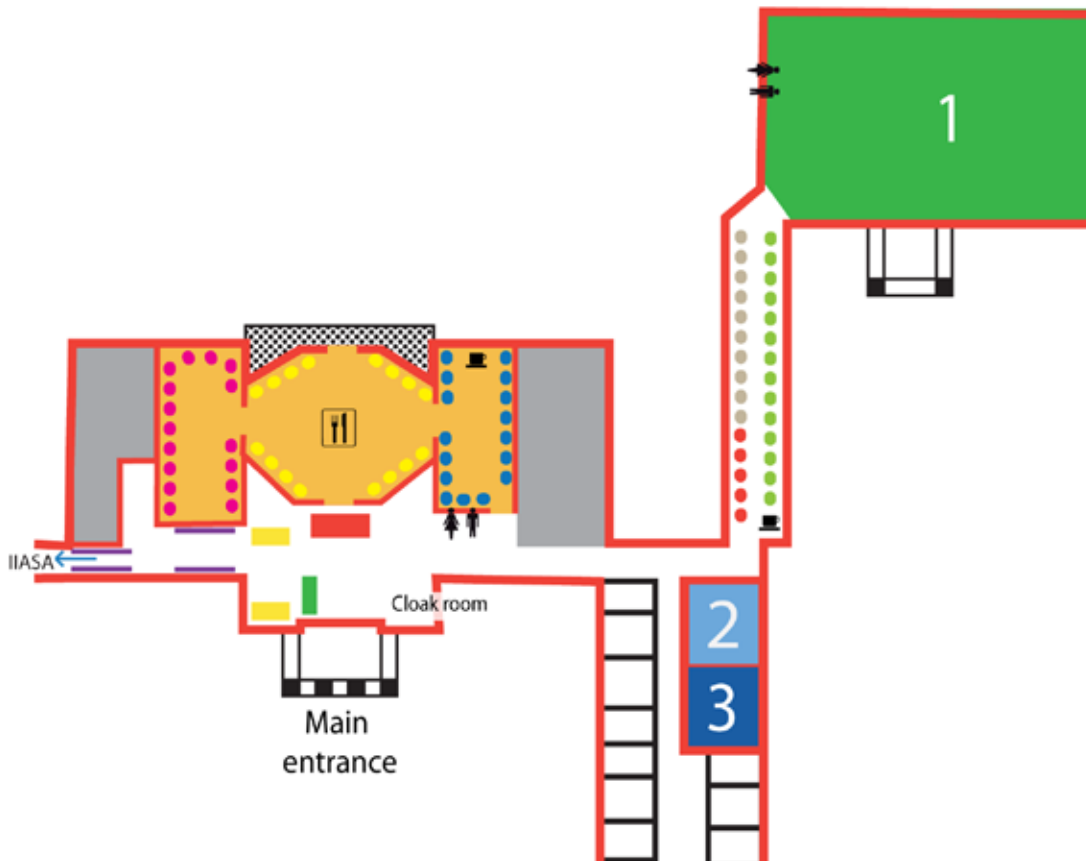
Hotel Alpha
 Buchfeldgasse 8, 1080 Vienna
 Telephone: +43 (0)1 4035291
 E-Mail: reception@hotelalpha.at

Motel One Vienna-Staatsoper
 Elisabethstrasse 5, 1010 Vienna
 Telephone: +43 (0)1 5850505
 E-Mail: wien-staatsoper@motel-one.com

Hotel De France
 Schottenring 3, 1010 Vienna
 Telephone: +43 (0)1 313 680
 E-Mail: reservation@hoteldefrance.at

K&K Hotel Maria Theresia
 Kirchberggasse 6, 1070 Vienna
 Telephone: +43 (0)1 521 23133
 E-Mail: reservation.mth@khotels.at

Radisson Blu Style Hotel
 Herrengasse 12, 1010 Vienna
 Telephone: +43 (0)1 22 7800
 E-Mail: reservations.style.vienna@radissonblu.com



- Registration
- Poster desk
- Information desks *
- IIASA display

POSTER THEMES / LOCATIONS

- S1: Requirements for Methodological Advances in Systems Analysis
- S2: Trans-disciplinary Inspiration in Systems Thinking
- S3: The Art and Craft of Systems Analysis
- S4: New Methods for Understanding Complex Systems
- S5: Addressing Diversity in Social Systems
- S6: Devising Integrated Solutions

* Publications, capacity building activities, donor center, Alumni Association

CONFERENCE CENTER LAXENBURG

- All presentations/Sessions (1)
- Conference secretariat (2)
- Working space (3)
- Lunch
- Coffee and drinks station
- Toilets

Conference Partners



IIASA is hosting Systems Analysis 2015 in collaboration with The Institute for Operations Research and the Management Sciences (INFORMS), USA; the Complexity Institute at Nanyang Technological University, Singapore; and the Santa Fe Institute, USA.

About INFORMS



INFORMS is the leading international association for professionals in analytics and operations research (OR). INFORMS advances research, and develops and promotes best practices in analytics and OR through collaboration, knowledge sharing, and professional development. INFORMS helps business, government, and other organizational professionals make better decisions to drive value to their organizations and society. Our certification program (CAP®), highly cited publications, educational meetings and conferences, continuing education, industry and process-focused networking communities, competitions, and recognition provide professionals with the knowledge and connections they need to achieve ever greater value for their organizations. Further information about INFORMS, analytics, and operations research is at www.informs.org or @informs.

About the Complexity Institute at Nanyang Technological University, Singapore



Complexity Institute

The Complexity Institute at Nanyang Technological University came into existence in April 2014, with the goal of becoming a global center for complexity research. Located in Singapore on the campus of Asia's fastest rising young universities, the Institute is a center for transdisciplinary research and teaching on complexity and complex adaptive systems. It studies how interactions within a system and its environment generate its dynamical patterns of behavior. Further information about the Complexity Institute is at www.complexity.ntu.edu.sg



SANTA FE
INSTITUTE


About the Santa Fe Institute

The Santa Fe Institute is a private, not-for-profit, independent research and education center, founded in 1984, where leading scientists grapple with some of the most compelling and complex problems of our time. Researchers come to the Santa Fe Institute from universities, government agencies, research institutes, and private industry to collaborate across disciplines, merging ideas and principles of many fields — from physics, mathematics, and biology to the social sciences and the humanities — in pursuit of creative insights that improve our world. Further information about the Santa Fe Institute is at www.santafe.edu

About the Conference

Systems analysis is one of the few research approaches that has both the breadth and depth to identify smart pathways through the complex nexus of increasing globalization, shifts of economic and political power, taxing environmental challenges, and unpredictable social conflicts to reach a world that accommodates the needs and aspirations of different groups and respects the limits imposed by the planet itself. The conference Systems Analysis 2015 will highlight recent advances, current gaps, and untapped disciplinary potentials in the field of systems analysis.

Follow the conference on social media:

 @IIASA Vienna or #systemsanalysis15

 www.facebook.com/iiasa

Check out the conference website for live webstreaming during the conference and afterwards you will find speakers' presentations, videos of the lectures, and conference photos: sa2015.iiasa.ac.at

About IIASA

The International Institute for Applied Systems Analysis (IIASA) is an international scientific institute that conducts research into the critical issues of global environmental, economic, technological, and social change that we face in the twenty-first century. Our findings provide valuable options to policy makers to shape the future of our changing world. IIASA is independent and funded by scientific institutions in its member countries in Africa, the Americas, Asia, Oceania, and Europe. In November 2015, these were:

AUSTRALIA Commonwealth Scientific and Industrial Research Organisation (CSIRO)

AUSTRIA The Austrian Academy of Sciences

BRAZIL The Center for Strategic Studies and Management in Science, Technology and Innovation (CGEE)

CHINA The National Natural Science Foundation of China (NSFC)

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)

INDONESIA The Indonesian National Committee for IIASA

JAPAN The Japan Committee for IIASA

KOREA, REPUBLIC OF National Research Foundation of Korea (NRF)

MALAYSIA Academy of Sciences Malaysia (ASM)

MEXICO Mexican National Committee for IIASA

THE NETHERLANDS The Netherlands Organization for Scientific Research (NWO)

NORWAY The Research Council of Norway (RCN)

PAKISTAN The Pakistan Academy of Sciences

RUSSIAN FEDERATION The Russian Academy of Sciences (RAS)

SOUTH AFRICA The National Research Foundation (NRF)

SWEDEN The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (FORMAS)

UKRAINE The Ukrainian Academy of Sciences

UNITED KINGDOM Research Councils of the UK

UNITED STATES OF AMERICA The National Academy of Sciences (NAS)

VIETNAM Vietnam Academy of Science and Technology (VAST)

Keep in Touch with IIASA

Sign up for free publications and newsletters from IIASA at www.iiasa.ac.at/keepintouch

Conference Feedback

Let us know what you thought about the conference at sa2015.iiasa.ac.at/feedback

ISBN 978-3-7045-0152-3



International Institute for Applied Systems Analysis
Schlossplatz 1, A-2361 Laxenburg, Austria
Tel: +43 2236 807 Fax: +43 2236 71313
www.iiasa.ac.at