Early History: 1966-1972

What we know today as the International Institute for Applied Systems Analysis (IIASA) came out of an initiative by President Lyndon Johnson in 1966. In December of that year Johnson asked McGeorge Bundy to explore with the Soviet Union, U.S. allies, and Eastern Europeans the possibility of establishing an institute to study problems common to advanced industrial societies. Bundy had recently resigned as Johnson's Special Assistant for International Security Affairs to become President of the Ford Foundation. Johnson's initiative had two motivations. First, it was one of a number of "bridge-building" initiatives intended to reduce East-West tensions by increasing contacts through cooperative constructive enterprises of common interest to the U.S., USSR, and their respective allies. But second it was also intended to benefit all countries by expanding knowledge and use of the new techniques of systems analysis. Hitherto these had been used mostly, with considerable success, for military purposes. The institute would thus both advance systems analysis research and help disseminate systems analysis expertise throughout the industrialized world to the general benefit of all societies. In the decision memo for the President that triggered Bundy's assignment, Deputy Special Assistant for National Security Affairs Francis Bator wrote,

> "those of us who have worked on the idea have in mind an institution based on the proposition that <u>all</u> advanced economies -- capitalist, socialist, communist -- share the problem of efficiently managing large programs and enterprises: factories and cities, subway systems and air traffic, hospitals and water pollution. There is great demand -- in Russia and Yugoslavia as well as the

UK and Germany -- for the new techniques of management designed to cope with these problems."

Bundy consulted initially with U.S. and western academics, business leaders, Executive Branch officials, Congressmen, and ambassadors from the Soviet Union and several U.S. allies, and he commissioned a study by RAND on the feasibility of such an institute.[1] The results of the consultations and of the study proved sufficiently promising so that in May he traveled to London, Moscow, Paris, Bonn, and Rome, together with Eugene Staples of the Ford Foundation and, in Moscow, Carl Kaysen, Director of the Institute for Advanced Study at Princeton University. On all their stops they found considerable interest in increasing international cooperation in the study of large common problems and strong support for Johnson's initiative.

In the Soviet Union Bundy's opposite number was Jermen Gvishiani, Deputy Chairman of the State Committee for Science and Technology and son-in-law of Soviet Premier Aleksei Kosygin. In the UK and Italy the key players were, respectively, Sir Solly Zuckerman, Chief Scientific Adviser to Prime Minister Harold Wilson, and Aurelio Peccei, founder of the Club of Rome. In France it was Pierre Massé, President of Electricité de France. All shared the U.S. interests of reducing East-West tension and spreading the techniques of systems analysis, but each negotiator also had separate interests of his own. The Soviets had a particular interest in incorporating modern techniques of forecasting in their planning process. They were enamored of large-scale systems, believing that systems analytic successes in military applications would be transferable to the increasingly complex and interdependent problems of modern civil societies. As IIASA's first Director Howard

Raiffa later put it, the Soviet leaders hoped that with these methods and a big enough computer they could finally make Marxist economics work as effectively as envisioned by its original proponents. Nonetheless, they also preferred that the institute focus on theoretical research rather than on applications that might examine Soviet experiences in too cold and unfiltered a light. Solly Zuckerman, on the other hand, preferred an institute focused wholly on applications. He was also very skeptical of the global modeling championed by Aurelio Peccei's Club of Rome and featured in *Limits to Growth*.[2] In addition to Peccei, both Gvishiani and Rennie Whitehead, who later represented Canada in the negotiations, were members of the Club of Rome. But Zuckerman had an ally in the U.S. where the National Academy of Sciences (NAS) shared his dim view of global modeling.

In February of 1968 Zuckerman invited representatives from the U.S., the Soviet Union, France, the Federal Republic of Germany, and Italy to a meeting at the University of Sussex. As had been the case in the initial discussions, participants would take part as individuals rather than as representatives of their respective governments, although it was generally understood that all were in close contact with their governments. However, the day before the meeting Gvishiani pulled out. His formal reason was a flare-up of tensions in Berlin, but the real reason, as he conveyed several months later to Peccei and Zuckerman, was that Zuckerman had not matched his invitation to the FRG with one to the German Democratic Republic.

Gvishiani and the Soviets remained seriously interested, but the "German problem" was equally serious. The U.S. and FRG governments would simply not provide funding for an institute in which the GDR was a member. Conversely, the Soviet Union had a vested interest in equal treatment for the GDR as a sovereign nation in its own right. The eventual solution was to make the institute non-governmental. Rather than the United States and the Soviet Union being members, for example, the National Academy of Sciences and the Soviet Academy of Sciences would be members. More importantly the FRG and GDR members could be the Max-Planck Institute and the Academy of Sciences of the GDR. Neither German government would have to recognize the other.

The next major step came in July 1969 at a meeting of Bundy, Peccei, Zuckerman, and Gvishiani in Moscow. In addition to a written aide-memoire outlining a governance structure for the institute, the meeting produced a key oral understanding. The institute's Council Chairman would be from the USSR, the Director from the U.S., the location would be in the UK, and, at the suggestion of Gvishiani, the sole official language would be English. The provision that the institute be located in the UK did not survive the subsequent British expulsion of hundreds of Soviet diplomats for spying. But the other three provisions held substantially longer. English is still IIASA's sole official language. The Director has always been from the U.S. except for 1981-1984 when a Canadian, Buzz Holling, held the post. And it was not until June 1997, as IIASA neared its 25th anniversary, that the IIASA Council was chaired by anyone other than the Soviet or, after 1990, Russian representative.

1969 also marked the beginning of Richard Nixon's presidency. Philip Handler, President of the NAS, took over the lead U.S. role from McGeorge Bundy. Through the next three years until IIASA's formal founding in October 1972 Handler and Gvishiani wrestled with three main disagreements -- location, the relative authority of the Council and Director, and the relative importance of methodological and applied research. The Soviets wanted to locate the institute in Vienna. The Americans preferred Fontainebleau in France. The Soviets wanted a relatively powerful Council. The Americans were concerned that the Director have the flexibility and authority needed to run a first-class research operation. The Soviets were hesitant about research moving beyond methodology. Westerners believed that, to be of value, methodological research on systems analysis had to be continually tested by experience in actual application, and therefore applications were essential if the institute was to be worthwhile.

The location issue was formally resolved in favor of Vienna, by a split vote, less than a month before IIASA's founding. The deciding factor against France was that the French required an intergovernmental agreement. This the U.S. and FRG considered impossible as long as there was a member organization from the GDR. On the second issue, ultimate authority for hiring and firing ended up with the Director, although a member organization could require that any recruits from its country come from a list it prepared. The only quotas in the final charter are that two-thirds of research scholars must come from countries with member organizations and that "Each member institution shall have the right to have at least one research scholar selected from among its nominees..." The third issue, the balance between methodological and applied research, has been one of continuing discussion and evolution. As the Soviet NMO, and indeed other members, gained experience with IIASA, the range of acceptable applications expanded. A project on demography, for example, was originally vetoed by the Soviet NMO. A year later, however, a Soviet review criticized IIASA for lacking just such a project, and the Soviet NMO became more accommodating. In the end, one of IIASA's considerable success stories resulted from a collaboration between an American demographer, James Vaupel and a Soviet mathematician, Anatoli Yashin. A second example concerns research on negotiations. Initially there was real reluctance to touch topics close to existing international negotiations. In 1974 IIASA's Director Howard Raiffa proposed a summer workshop on the Law of the Sea negotiations in which workshop participants could explore models analyzing issues addressed by the negotiations and generally share ideas and analyses in an informal setting. The proposal was rejected by IIASA's Council as too "political." In contrast, twenty years later the Council's strong support for research addressing international negotiations on population and development, global warming, and other environmental issues was almost taken for granted.

During the final two years of negotiations the parties also finally settled on the eventual name. Many had been proposed and used at various stages in the discussions. Each word held the potential for disagreement. Should it be the Center for Study of the Common Problems of Industrialized Societies, or would it be better to refer to advanced societies? Should the word international be included? What constitutes a society? Should it be a center or an institute? Should center be spelled "center" or "centre"? Particularly problematic were words like cybernetics or operations research that carried connotations that one or another of the parties considered at odds with its view of the institute. Applied systems analysis was a phrase Howard Raiffa plagiarized from the title of a book he had recently written. No one had preconceived notions of its meaning, and as a new phrase for a unique institute it held the right mix of specificity and ambiguity to be acceptable to all.

The formal founding of IIASA finally came on October 3-4, 1972 in London. There were founding members from twelve countries: Bulgaria, Canada, Czechoslovakia, France, FRG, GDR, Italy, Japan, Poland, the UK, the U.S., and the USSR. Jermen Gvishiani was elected the first Chairman of the governing Council, and Howard Raiffa was appointed the first Director.

IIASA's Research

It is now a quarter century since IIASA's founding and more than thirty years since Johnson's original assignment to McGeorge Bundy. To date the Institute has succeeded against both its objectives: bridge-building across the East-West political divide and advancing both the theory and application of systems analysis.[3]

IIASA's research success has come more from how the Institute assembles from the bottom up the components of a successful analysis than from any definitive top-down formula for carrying out such an analysis – or even for defining what "applied systems analysis" really means. According to IIASA's strategic plan,

> "The Institute's strategic goal will be to conduct international and interdisciplinary scientific studies to provide timely and relevant information and options, addressing critical issues of global environmental, economic, and social change, for the benefit of the public, the scientific community, and national and international institutions."

But even IIASA's staff would be hard pressed to provide a concise consistent definition of applied systems analysis beyond defining it simply as "what IIASA does." So what does IIASA do?

First, IIASA brings people from different disciplines and countries together for sustained research under one roof. In this it is almost unique and distinctly different from most international exchanges and workshops that bring groups together for a short time. This fosters specialized interdisciplinary and international connections that are more likely to create and consolidate real conceptual breakthroughs. William Clark cited several examples in his presentation at the conference. One such unexpected successful connection was between ecologists intent on descriptive analyses of pest infestations and operations researchers working on optimization and dynamic programming techniques. The result was both new analytic methods and fundamentally new ways of looking at and reformulating practical real-world policies, including a shift in policy focus from spraying bugs to cutting trees. A second example is connections prompted by Tjalling Koopmans, a Nobel laureate and researcher at IIASA in the 1970's. Koopmans noticed commonalties in the instabilities encountered by IIASA researchers studying populations, climate, organic chemistry reaction patterns, and macroeconomics. He brought them all together in several workshops that eventually led to significant advances in non-linear dynamics. A third example is one we will return to in more detail below, IIASA's RAINS model (**R**egional **A**cidification **In**formation and **S**imulation).

Second, IIASA seeks to increase the comprehensiveness of existing analyses. In the early 1980's for example, nearly every country was busy producing national models of its energy supplies and demands. Gaps between the two indicated what a country could expect to import. IIASA's study was the first to ask if all these expected imports might not add up to more than the available exports. What were the prospective global gaps between energy supply and demand, and what might be done to close them? Twenty-five years later IIASA is exploring the possibility of similar transnational gaps relating to social security. Population aging in industrialized countries is prompting numerous national studies analyzing current and alternative national pension policies. National policies, however, will have international repercussions through their effects on multi-national employers, migration, and monetary flows. IIASA is exploring how best to provide a global perspective that contributes today to national pension studies what its energy research contributed in the 1970's to national energy studies. Increasing the comprehensiveness of existing analyses does not always mean adding a global perspective. In IIASA's current energy research, for example, it means linking greenhouse gas emissions calculated by energy models to climate models, RAINS, and models of international agricultural production, consumption, and trade.

Third, IIASA's most effective projects have simplified complexity while maintaining credibility with both scientists and decision-makers. For an analysis to be used it must be understandable, and it helps greatly if it can be presented in simple clear terms. The objective of simplification can be at odds with the second feature of IIASA's approach listed above, increasing comprehensiveness. The challenge is to do both thereby providing relatively simple aggregated models in the end that rest on underlying detailed comprehensiveness analyses. Sometimes the detailed models are developed at IIASA. Sometimes they are adapted or incorporated whole from other institutions. In both cases, it is important that the Institute's research and applications maintain credibility and support from the scientific community through peer-reviewed publications and direct reviews at workshops and conferences.

Fourth, IIASA engages decision-makers throughout its analyses. This has two effects. It increases the decision-makers' understanding and ownership of the analysis, and that makes it more likely that the analytic results will influence eventual decisions. Second, it allows IIASA to respond early and often to the needs and preferences of decision-makers. The result is an analysis more likely to address the issues that matter most to decision-makers, and to offer answers to the questions they are most likely to ask.

Fifth, IIASA builds networks extending beyond its walls that incorporate new mixtures of disciplines. The international and interdisciplinary connections fostered under the first feature of IIASA's approach listed above are now complemented by a network of alumni approaching 2,000 researchers. And IIASA actively builds networks well beyond its own alumni. In the 1970's Howard Raiffa navigated between global modeling's strong advocates (e.g., Aurelio Peccei) and its strong detractors (e.g., Solly Zuckerman) by establishing IIASA as a site for regular presentations and reviews of global models. IIASA would not build its own global model but would host regular conferences to review and document the research of others. Global modelers liked the forum this provided. The critics liked the requirement for documentation and the opportunity for skeptical review. IIASA's network involved both. Since the 1981 publication of IIASA's initial global energy study, its subsequent research in the field has always included annual meetings of the International Energy Workshop (IEW). The IEW is run jointly by IIASA and Stanford University and annually assembles approximately 50 energy research groups from around the world to compare their models, their results, and their plans. In the field of natural resources and the environment essentially every international science program in the past two decades has been influenced by the research and networks begun at IIASA in 1972. Ideas and connections initiated at that time through IIASA have persisted and expanded and now thoroughly permeate international efforts such as the International Geosphere-Biosphere Programme and the Intergovernmental Panel on Climate Change.

The Transboundary Air Pollution Project and RAINS

Our presentation of these five characteristics of successful systems analyses at IIASA does not mean every project in IIASA's first quarter century has scored an A^+ on all five features. Rather those that have been most successful have better incorporated these features in their approaches than have less successful projects. One of IIASA's most successful projects and best examples of all five characteristics is the Transboundary Air Pollution (TAP) Project, which began in 1983 and developed the RAINS model of the impact of acidification in Europe. The TAP Project and RAINS exhibit each of the characteristics mentioned above, particularly simplification and maintenance of credibility in the eyes of both scientists and political decision-makers, early and continual involvement of policy-makers and scientists together in the formulation of key questions and the periodic review of progress, and the building of scientific and political networks beyond IIASA's walls capable of taking on a life of their own, continuing the work, and providing critical data inputs to the continued improvement and updating of the models developed at IIASA.

The origins of the TAP Project lie in the Convention on Long-Range Transboundary Air Pollution (LRTAP), which was adopted in Geneva on 13 November 1979 and entered into force on 16 March 1983.[4] By May 1993 its membership had grown to 39 parties, including the European Union. In addition, EMEP (Cooperative Programme for the Monitoring and Evaluation of Air Pollution in Europe) had been established as early as 1977 under the auspices of UN/ECE (Economic Commission for Europe) with the cooperation of WMO (World Meteorological Organization) and, initially, UNEP (United Nations Environment Program). The creation of the IIASA RAINS model began shortly after LRTAP came into force as a means for providing scientific support for negotiations under the LRTAP Convention. By the late 1980s it began to play a central role in the negotiations. As stated in a 1989 report from a task force under the Executive Body of the Convention:[5]

> "An integrated assessment model that can assist in cost-effectiveness analysis is now available... The Task Force... recommends that the RAINS model be used by the Parties to the Convention, the Executive Body, and the various subsidiary bodies."

The model was to estimate environmental impacts for all of Europe, including the European part of the USSR, with a resolution of 150 km x 150 km. Simulations with the model were to extend back to 1960 for historical perspective, and forward to 2040 to insure that long-term consequences of different control policies would be adequately taken into account. Owing to the large spatial coverage and time horizons involved, the time steps used in the calculations had to be rather large (seasonal or annual). Both the long time horizon and the large spatial grid were necessary because of the sensitivity to short-term local variability in meteorological conditions of the atmospheric transport model used to convert pollutant emissions into environmental impacts. The validity of this averaging was subsequently checked by using the model to reproduce historical trends in pollutant deposition from 1960 to the time of application of the model, with sufficient agreement to provide reasonable confidence in using the model to make projections into the future with the same assumptions.

The RAINS model was subdivided into six submodels for each pollutant to be studied, as follows:[6]

1) Pollutant emissions and costs of reducing them

2) Atmospheric transport and deposition

3) Soil acidification

4) Lake acidification

5) Groundwater sensitivity to acidification

6) Forest impact of pollutants (indirect impact of soil acidification on forest health, and the direct effect on trees from exposure to gaseous forms of pollutants).

In the initial use of the model the only pollutant considered was SO_2. Later, after 1990, NO_x and NH_3 (ammonia) were added in order to take into account active forms of nitrogen as well as sulfur. More recently tropospheric ozone has also been added.

For 1) it was necessary to have energy projections for each country and their emissions under various assumptions regarding installation of technologies for reducing emissions. For this purpose so-called "energy pathways" were developed from official projections of each of the participating governments for twelve energy sources and six economic sectors from 1980 to 2000. These projections were taken as givens for most of the scenarios computed. However, the governments were later each invited to develop two alternate energy "pathways", one a "high conservation" pathway and the other a high natural gas pathway. The pollution mitigation technologies could be applied to these pathways as well as to the original ones. The conservation pathway generally contemplated phasing out of nuclear power as well as emphasis on the maximum feasible use of renewable energy sources in addition to hydropower. However, it was carried out for only 10 of the 27 countries, which accounted for only one sixth of the total energy production of the 27 countries.

In the case of sulfur, five "options" were considered in principle for reducing emissions. These were: energy conservation, fuel substitution, use of low sulfur fuels or desulferized fuels, desulferization during the combustion process, and desulferization of the flue gases after combustion.[7] Only the rates of installation of the last three of these were taken as variables that could be adjusted to control emissions in the future. A set of costs for installing these technologies that was compatible across countries was developed. However, as will be discussed later, the first two options were not treated as variables, but were simply taken from the official projections provided by governments.

The second set of submodels after energy pathways and emission reduction options and their costs dealt with atmospheric transport processes and resulted in transfer matrices based on the EMEP model.[8] The emissions derived from the first set of submodels were used as input and transformed into deposition patterns for all the countries including the European parts of Russia. The output of these submodels was then offered as a set of options for the user, including maps with isolines for sulfur and nitrogen deposition, colored maps with deposition patterns subdivided into classes of deposition, and tables showing the source of the calculated deposition at a particular point in Europe designated by latitude and longitude. With these output displays comparisons among scenarios and emission abatement strategies could be carried out.

The remaining four submodels for soils, lakes, groundwater, and forests were heavily dependent on knowledge and data provided by a number of collaborating institutions and experts in various parts of Europe. For example, one of the most complicated impact questions arose in the case of forests. Here the "SO_2 forest impact model is based on empirical data of forest dieback from Czechoslovakia's Erzgebirge Mountain region... damage to trees is assumed to occur if the accumulated dose exceeds a threshold level, which depends strongly on climate... Temperature is used in the model as an indicator of climate stress... threshold levels and doses in the model are decreased as climate stress increases... This method provides a consistent way to take into account the different levels of climate stress experienced by trees at different elevations and latitudes in Europe."[9]

This evaluation was done within the framework of EMEP, and has been established as an official international collaboration among the parties to the Convention. This collaboration has also included financial support from almost all the parties. Moreover, through review meetings in which scientists from all over the world participated, it was possible to convince all parties of the quality of the EMEP model. This was further enhanced by regular review meetings which took place at IIASA. These meetings covered each of the submodels one by one, and three times convened larger meetings to review the model as a whole, particularly the linkages between the submodels, and to discuss the problems with these linkages. These integrated review meetings also provided a forum in which policy advisers to governments could appraise the state of the model and assess its limitations and help formulate questions they deemed most important for the models to address from a policy standpoint.[10] Assessment was generally done in a non-confrontational, cooperative fashion where the credibility of information derived from self-reporting by individual participating governments was taken for granted.[11]

The original goal in designing the RAINS model had been that a policy-maker would sit at a computer monitor and operate the model during actual international negotiations. Although this idea was abandoned as impractical at an early stage, user friendliness remained a very important design criterion, and the models were implemented for personal computers so that alternative scenarios could be tested in the presence of policy-makers more or less in real time so as to influence discussions. At general review meetings in 1984 and 1986 representatives from many ministries in Europe and North America were briefed in depth on RAINS and its potential uses, and they in turn offered valuable advice about the kind of questions they wanted the model to address. It was because of their input that the decision was taken to extend considerably the first RAINS submodel (dealing with energy scenarios and abatement strategies). The participants also pointed out that the RAINS model should include all the relevant pollutants. This advice led IIASA to implement submodels for NO_x and NH_3 (emissions and cost calculations). More recently tropospheric ozone has also been included in the model in response to the evolving agenda of governments and their negotiators.

Two basic ways of using the RAINS model have been developed: scenario analysis and optimization analysis.[1] To conduct a scenario analysis, a user begins by specifying an energy pathway and a control strategy. The implications of these inputs can then be

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[1] IIASA continues to improve and expand RAINS. Recent developments are not included in the description below, which presents RAINS as it was at the initial phases of the negotiations leading to the 1994 Second Sulfur Protocol under the UN/ECE Convention on

examined. The user has the option of examining output from any of the submodels, e.g., sulfur emissions in a particular country or group of countries, costs of sulfur control for each country, sulfur deposition or SO_2 concentration at different locations in Europe or mapped for all of Europe, or maps showing the time history of soil acidification, lake acidification, or risk to forest area from exposure to SO_2. This can be an iterative process, in which the user normally examines an output implied by one set of inputs and then, based on a subjective judgment, selects an alternative control strategy for comparison with the previously selected strategies.

Alternatively, in optimization analysis, the user can start with goals of environmental protection and/or economic constraints and, work the model backward as it were to determine a country by country strategy in Europe to accomplish these goals, using a single objective linear programming approach which can accomplish one of the following tasks:

--Given a fixed upper limit on expenditures for emissions reductions, determine where the most sulfur can be removed from emissions.

--Given an environmental target (sulfur concentration or deposition) in a specified region of Europe, determine where the minimum amount of emissions should be removed to meet the target.

--Given an environmental target, determine where emissions should be reduced to minimize the cost of removal and still meet the target.

Long-range Transboundary Air Pollution.

As indicated previously, fuel switching and conservation have not yet been treated as variables in the optimization process. This has meant that trade-offs between, say, energy conservation or switching to nuclear from coal for electricity generation as opposed to installing desulferizing equipment were not considered as "options" on a country by country basis in the optimization process. In the long-run, of course, this is a serious limitation in the applications of the model so far used. The justification for this restriction was given in the following terms:[12]

> "Although fuel switching is often an effective way to reduce emissions, it may be limited for historical, institutional, or political reasons (e.g., N.E. Hay, ed. Natural Gas Application for Air Pollution Control, American Gas Association, Liburn, GA, 1986). Because of these limitations, which are specific to a country or a site, it is extremely difficult to derive reliable cost estimates for substitution strategies at the European level. In addition, even a rough estimate must account for the costs of changing the infrastructure to the new fuel demand conditions; this would require extensive information on the capacities and age structure of the European energy system... because the costs of fuel substitution policies might have a large effect on the economy (e.g., the trade balance), a factor that is not included within ENEM, the costs of fuel substitution have been excluded from ENEM."

Furthermore, these costs and intangible considerations will be heavily dependent on future political developments such as the formation of and membership in the European Union which might make trade considerations less salient, and the adoption of a common currency.

This could prove to be a very serious limitation on the use of RAINS, since the cost variables that are omitted are potentially larger in their impact on emissions and environmental impact than those which are considered in the other three mitigation options. This is particularly heavily effected by nuclear power projections (and to a lesser extent renewables) since in some cases the phasing down of nuclear power will considerably increase the amount of sulfur control that has to be used as well as affecting how it needs to be allocated among countries. On the other hand, with greater integration of the European economies, and improved data collection on power plants, there is no reason that fuel switching and conservation cannot eventually be incorporated into the optimization process, and this is currently being considered.

Even with this serious limitation, however, RAINS can show that dramatic improvements in cost-effectiveness can be achieved by allowing the percentage sulfur emission reduction required to vary among countries. As one specific example, we can consider the following:

In 1991 the estimated cost of Current Reduction Plans (from the 1979 convention) was about DM 12 billion per year. One possibility was that each country would invest its committed portion of this sum within its own borders. Alternatively each could put its share into a common fund to be redistributed among the countries in such a way as to achieve the greatest level of environmental improvement throughout Europe (defined as the lowest attainable level of sulfur deposition in Europe as a whole for a given financial investment). It was estimated that for the same financial investment this alternative would reduce the peak deposition in Central Europe by roughly 40 percent in comparison with Current Reduction

Plans by directing money to those countries which are the major contributors to the high deposition levels and can reduce their emissions most cheaply. The result would be a decrease in the area of forest soil in Central Europe with a pH < 4.0 from 17 percent to 4 percent between 1995 and 2000.[13]

These principles involved in the optimization procedure developed in RAINS have now been embodied in a formal agreement. The most recent regulatory step is the revised sulfur protocol which was signed in Oslo in June 1994. It is both binding and specific, including both specified targets and time tables. The key feature of the agreement is that these elements are combined with flexibility on the basis of so-called "critical loads." The crux of this approach is that emission reductions should be set based on the varying effects of air pollutants, and the variations in abatement costs among countries, rather than by choosing an equal percentage reduction target for all countries involved.[14] It is probably still too early to foresee how well the goals of the 1994 protocol will be met. In this respect, it is well to keep in mind how difficult it is in practice to separate the effects of formal regulatory agreements from other factors such as current political mindsets and well publicized anecdotes of dubious scientific validity but dramatic public impact such as the "Waldsterben" crisis of 1981/82 in Germany which served to focus public attention and political energy on the control of acid rain.[15] The situation has been nicely summarized by Wettestad in the following terms:

> "Summing up: a regulatory development may be discerned, with regulations gradually becoming more binding, specific and more fine-tuned to ecological and economic variations among the countries. However, the impact implications of this regulatory

> development are quite tricky. It seems that substantial emissions reduction took place at a time before regulations became more specific and binding, and the main part of the more recent emissions reductions probably has nothing to do with the international regulations and/or their design. The possible 'softer,' more diffuse 'tote-board'[16] effects remain to be substantiated."

Nonetheless however well the parties to the second sulfur protocol do eventually in meeting their commitments, and however much of any success is attributed by future historians to the protocol itself, the TAP Project is a good example of how IIASA can carry out systems analysis first to develop new valuable policy insights, and second to encourage the incorporation of these insights in actual policies.

Evolution and Resiliency

Again, the presentation above of the five characteristics of successful systems analyses at IIASA does not mean every project in IIASA’s first quarter century has scored an A^+ on all five features. Rather those that have been most successful, such as the TAP Project, have better incorporated these features in their approaches than have less successful projects. This, rather than any top-down recipe, we believe has been responsible for IIASA’s continuing success over 25 years even as issues and expectations in the field of systems analysis have changed.

Two examples of such changes were presented by the panel. Clark cited IIASA’s ecological research. At the time of IIASA’s founding the focus was on methods and applications to maximize yields from various natural resource populations. IIASA had a number of successes in this area, advancing the field by introducing both optimization techniques as discussed above and adaptive resource management methods.[17] By the mid 1980's attention had turned to issues of global environmental change and transboundary pollution, of which the RAINS model described above was the centerpiece. Another example is the Institute's work on water pollution and climate change.[18] In the 1990's IIASA's ecological research has expanded to include human behavior as an integral part of the ecosystem, and this has led to the incorporation of a much larger social science component with recruitment of more social scientists and the extension of the Institute's networks into the international social science community. IIASA's recent project on the Implementation and Effectiveness of International Environmental Commitments is a good example of this effort.

For his example of changes in systems analysis and IIASA over 25 years Alan McDonald turned to the field of energy. In 1975 as a young engineer at General Electric's Fast Breeder Reactor Department in Sunnyvale, California McDonald had been given the task of determining safety criteria for a design known as the prototype large breeder reactor (PLBR). He would calculate how safe the reactors needed to be, and design engineers would then design the PLBR to these specifications. The idea that systems analysis could provide a definitive, unique answer to the question of how safe a nuclear reactor should be seems hopelessly naïve today, but it was not discouraged as naïve at the time. Although the search for such a definitive safety standard was ultimately unsuccessful (as was the PLBR), what is significant is that the best and most useful work at the time was coming out of IIASA. The Institute was leading the world in exactly the research for which McDonald had turned to systems analysis. At the time IIASA was only three years old.

Today setting safety standards for LULU's (locally undesirable land uses) such as nuclear reactors is more often seen as a negotiation among multiple parties with different information, expectations, and preferences. In such a negotiation there is no single decisive fairness principle that is theoretically and practically perfect for all situations. Rather there are a number of fairness principles that in practice can serve as focal points around which negotiators can coordinate their expectations.[19] In their simplest forms fairness principles fall into three categories: parity, proportionality, and priority. Many can be characterized by common phrases such as "split the difference," "first come, first served," "take turns," and "returns proportional to investments." As parties gain familiarity and trust with each other, they can overlay combinations of simple fairness principles to create joint gains that can make all parties better off. The process of calculating and agreeing to such mutually beneficial, but more complicated combinations of fairness principles can be greatly facilitated by joint cooperative research. Many of IIASA's more recent projects play exactly this role. The TAP Project, and its role in shifting negotiators from an agreement based on equal percentage reductions by all countries to a less symmetrical but more cost-effect agreement, is an excellent example.

Epilogue

Even as systems analysis and the nature of IIASA's contributions have evolved over the last 25 years, so have the politics surrounding the Institute. With President Reagan U.S. policy toward the USSR shifted from bridge-building to isolation and pressure. The White

House terminated government support for U.S. membership at the end of 1982 and pressured the NAS into withdrawing as the U.S. NMO. The U.S. membership was transferred to the American Academy of Arts and Sciences in Cambridge, Massachusetts. Through the remainder of the 1980's the American Academy raised private funds, gradually built Congressional support, restored partial National Science Foundation (NSF) funding, and, by the end of 1989, through the crucial intervention of Allan Bromley as well as several other members of the Bush administration, backed by support in the Congress, persuaded the President to restore White House backing. Nonetheless the weakened U.S. participation halted and slightly reversed what had been a steady increase in IIASA's research budget through 1982.

With the end of the Cold War IIASA's members negotiated a new strategic plan for the Institute focused on global change including technological change, economic change, and environmental change. As noted above the Institute is very much involved in particularly the IPCC and IGBP as well as providing research leadership in the areas of transboundary air pollution, demography, and energy policy. Political challenges remain although they have changed since the 1970's and 1980's. Where the U.S. was an unreliable financial partner during most of the 1980's, the economic difficulties in Russia now make its annual contributions the largest recurring financial question mark. Where support for IIASA in the 1970's went against Cold War conventions, funding for IIASA must now contend with the fashion for cutting international research budgets not only in the U.S., but in some other previously strongly supportive countries as well. Throughout IIASA's basic strategy has remained unchanged – to provide the best that systems analysis has to offer even as the field and our expectations continue to evolve.

ENDNOTES

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