PNNL-SA-35437

China-Korea-U.S. Economic and Environmental Modeling Workshop

Conference Proceedings

Beijing, People's Republic of China

23-25 May 2001

Sponsored by the
U.S. Environmental Protection Agency

Hosted and Organized by the
China Energy Research Institute
Beijing Energy Efficiency Center
Pacific Northwest National Laboratory

Advanced International Studies Unit

Pacific Northwest National Laboratory

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Prepared for the U.S. Environmental Protection Agency under Contract number 15046

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Washington, DC 20024

Acknowledgments

This publication documents the third China-Korea-U.S. Economic and Environmental Modeling Workshop held in Beijing on 23-25 May 2001. The workshop brought together over 50 economic and environmental modeling experts from across the globe to review existing tools, identify future challenges, and strengthen the community of modelers between and within countries. It built on activities in earlier workshops held in Beijing during January 1999 and March 2000, and Seoul in March 2000.

The workshop was made possible through support from the U.S. Environmental Protection Agency (EPA). Paul Schwengels and Michael Shelby lead EPA's efforts to improve technical cooperation between Chinese and U.S. modeling experts. Other key contributors from EPA include Richard Garbaccio, Chris Botnick, Francisco de la Chesnaye, and John "Skip" Laitner.

China's Energy Research Institute (ERI) and the Beijing Energy Efficiency Center (BECon) made the arrangements in China for the workshop. Jiang Kejun of ERI superbly organized the event as well as providing technical expertise. Seung Jick Yoo organized the participation of experts from the Korea Energy Economics Institute (KEEI). Zhou Dadi and his colleagues at the ERI, including Zheng Shuang, Zhu Songli, and Li Yun deserve special thanks.

Jeff Logan organized the participation of experts from the United States and helped plan the agenda. Meredydd Evans reviewed a draft version of this document and provided useful feedback. Karen King, Paulette Wright, and Jay Wertenberger helped organize administrative details of the event.

We would especially like to thank the experts who gave presentations at the workshop. Their talks generated excellent discussion and made the workshop a success. Finally, we offer our thanks to each of the workshop attendees for helping to strengthen the community of economic and energy modeling experts in China and Korea.

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Executive Summary

The China-Korea-U.S. Economic and Energy Modeling Workshop was held from 23-25 May 2001 at the Oriental Garden Hotel in Beijing. It brought together over 50 Chinese, Korean and international experts to discuss technical modeling issues related to global climate change policy analysis. It is part of a larger effort by the U.S. Environmental Protection Agency (EPA) to engage key developing and transition economies in technical issues related to climate change mitigation.

Cooperation on economic and environmental modeling is intended to promote greater participation among developing and transition economies in global carbon mitigation efforts. The primary methodology used to achieve the goals focuses on building technical capacity for detailed economic analysis of climate change and related environmental policies. Developing and transition economies will be able to consider a more complete range of options to address the challenge of global climate change if their government research institutes, universities, and NGOs have better quantitative tools for climate policy analysis. U.S. interests are also advanced through a clearer understanding of economic, energy, and environmental trends in key countries, and how global responses to mitigate emissions might affect world markets.

Modeling of economic, energy, and environmental options can give decision-makers a stronger basis on which to develop policy agendas. Policymakers in the United States, for example, believe flexibility mechanisms such as carbon trading, joint implementation, and project-based crediting can dramatically reduce the total costs associated with mitigating carbon emissions. Developing countries might also find lower total costs in participating in voluntary targets or flexibility mechanisms by considering the co-benefits of lowering criteria air pollutants while mitigating carbon emissions. Furthermore, building analytical capability to model a wider suite of greenhouse gases may have a significant impact on policy decisions in many countries.

EPA has funded development of several economic and environmental models that can assist developing countries in climate policy. First, EPA supported development of a computable general equilibrium (CGE) model at Harvard University to simulate China's hybrid economy. The model has been successfully transferred to Chinese researchers and

is now being used to inform climate policy at the State Council. EPA continues to expand the model's capability and is currently adding the ability to simulate co-benefit policies.

EPA has also supported development of the Second Generation Model (SGM) at Pacific Northwest National Laboratory. The SGM is a global computable general equilibrium (CGE) model that characterizes China as a separate entity. Chinese collaborators are currently updating the China module to update the starting base year and add more sectors. The U.S. Department of Energy is also assisting Chinese researchers at Tsinghua University to develop their own version of MARKAL-MACRO.

Other universities, research institutes, and government agencies have also developed economic models that are useful in analyzing both country-specific and global carbon mitigation strategies. The Massachusetts Institute of Technology, Japan's National Institute for Environmental Studies, the University of Colorado, and the National Institute of Public Health and Environmental Protection in the Netherlands—to name just a few—have developed world-class models to simulate carbon mitigation policy.

In addition to building local capacity, other goals of the modeling workshops include obtaining country-specific information to help U.S. modelers improve the accuracy of their own simulations and promoting interaction between agencies, both American and those in developing countries. In China, for example, researchers and officials rarely come together to share information on their work and the EPA's modeling workshops give them an unprecedented chance to do so. Many U.S. modelers have also lauded the ability to gather country-specific information during meetings with colleagues in Korea and China. Developers of PNNL's SGM, for example, have redefined model development priorities and are better able to defend the results of their simulations based on information gathered at these workshops.

During this three-day workshop, 35 experts from China, Korea, the U.S., Europe, and Japan gave presentations on their modeling efforts that led to lively discussions and sharing of new information. A list of all participants is reproduced in Appendix A, while a list of presentations is contained in Appendix B. Electronic copies of most presentation material is reproduced in Appendix C.

Participants developed plans for future collaboration to begin dealing with some of the technical issues raised in the discussions. Future work includes plans for a follow-on workshop in 2002 where sensitivity studies will be compared on selected models. Chinese researchers are also developing a list of potential activities that includes creating a worldwide web site on energy and economic modeling, publishing a technical journal on modeling issues, and expanding the impact of new modeling efforts such as integrated environmental strategies (also known as co-benefit analysis) and non-CO_2 greenhouse gas mitigation options.

Rapporteur Notes

The following notes summarize presentations made by participants over the course of the three-day workshop.[1] Presentation material for most speakers is contained in the Appendix C. Appendices A and B contain a list of attendees and workshop agenda, respectively.

Workshop Presentations

Day One, 23 May

Session I – Introductory Remarks

Jiang Kejun – Introductory Remarks from China's Energy Research Institute

Jiang divided his presentations on recent modeling activities in China into three categories: modeling studies over the past year, the top-down macroeconomic models, and the bottom-up technology models. Jiang then provided some broader perspective on future goals for the modeling community in China. For instance, he said modeling research should be improved by paying more attention to model comparison and coordination. He also discussed the China module of the Asian Integrated Assessment Model (AIM) and the carbon forecasting study using LEAP.

Seung Jick Yoo – Introductory Remarks from Korea Energy Economics Institute

Yoo provided an overview of energy and environmental modeling in Korea, including research efforts at KEEI. Yoo described Korea's efforts to harmonize the Three E's (energy, economy, and environment). For the bottom-up approach, Korea is working on a long-term energy and emission forecasting model as well as the EFOM-ENV Model. With top-down models, efforts are concentrated on both national and global CGE models. Yoo presented a chart of projected energy demand in 2020 indicating that: LNG use will triple, nuclear power will double, and oil will continue to account for nearly 50 percent of total energy demand. Yoo also commented on recent trends in Korea's energy markets, including privatization of electric utilities and district heating companies, removal of price controls, and reform of tax structures. Korea will try to focus on a energy efficiency and clean environment with these new policies.

Paul Schwengels and Chris Botnick, Introductory Remarks from U.S. EPA

Schwengels began by describing the EPA Office of Atmospheric Programs' goal of seeking market approaches to mitigating air pollution. Voluntary technology programs as well as climate and stratospheric ozone policy programs form the basis of action. Schwengels also called attention to EPA's focus on technical cooperation with developing countries, including integrated environmental strategies, multiparty market mechanisms,

[1] For an online color version of these presentations, please visit PNNL's China E-News web page at http://www.pnl.gov/china.

and economic and environmental modeling. With regard to the latter, Schwengels listed four primary goals: (1) enhance cooperation among technical experts internationally; (2) exchange information and improve understanding of analysis and results; (3) encourage cooperation to improve methods; and (4) pursue informal opportunities to discuss policy implications. Past cooperation has been successful in improving communication and collaboration within and across countries, identifying several opportunities to enhance cooperation internationally, and developing mechanisms for continuing and enhancing cooperation. Schwengels, however, went out of his way to explain that the expert workshop is not a forum for explaining U.S. climate policy, debating specific negotiating issues, or launching basic research or model development programs. Instead, he believes the goals of this workshop are: (1) to give all parties a better understanding of key models, institutions, and ongoing work in all countries; (2) to provide opportunities for individual experts to establish and enhance working relationships with international counterparts; and (3) to develop ideas for possible follow-on actions by Chinese, Korean, and U.S. partners.

Chris Botnick followed with more specific arguments supporting targeted climate action. He stated that climate change is likely to be a serious worldwide problem and that each country subsequently has a unique responsibility. For instance, independent of each country's level of emissions, the U.S., Korea, and China can all contribute to environmental and economic modeling efforts, where some of the goals are to develop a technical understanding of climate change as well as potential impacts of policy and improving project baselines. Botnick gave a brief summary of U.S. economic analyses, which address issues such as alternate policy approaches, new technologies, sequestration options, research and development, emissions credit trading, and co-controls. Botnick next presented data on the variation in carbon emission reduction costs for a target of 30 percent below baseline levels by 2010—between ten different models, the costs vary from $50 to $400 per ton of carbon in the U.S. He also compared methane marginal abatement curves for coal, natural gas, landfills, and manure management for different countries. Botnick concluded by stressing that further cooperation is essential in order to promote the following beliefs:

- "When, where, and what" flexibility can lower costs;
- Acceleration of advanced technologies lowers costs;
- Co-control benefits offset costs; and
- Climate policies help remedy local and regional environmental degradation and pollution

Session II – Top-down Modeling Activities

John Reilly – MIT's Emission Prediction and Policy Analysis Model

Reilly gave an overview of the MIT computable general equilibrium model. Korean participants in particular had expressed a long-standing interest in learning about the Emission Prediction and Policy Analysis (EPPA) model. EPPA, a world model that is part of the larger Integrated Global Systems Model at MIT, includes both consuming and producing sectors where sales of goods must balance. Features of the model are described in the slides reproduced in the appendix.

Reilly presented a chart of energy intensity for developed and developing countries, which demonstrates a fairly rapid decline in energy intensity for developing countries around 2000 compared to earlier trends. China is the only developing country whose intensity has declined since 1980. The model also predicts that China's emissions will surpass those of the U.S. in 2030. Currently, modelers are incorporating methane emissions in EPPA.

The marginal abatement cost for a 25 percent reduction in U.S. carbon emissions is $300/tce compared to $50/tce in China. Reilly's group also performed a sensitivity analysis, which considered 10 and 30 percent reductions from a 2010 reference case. The three cases that were compared were a carbon-dioxide reference, a carbon-dioxide and methane case with no restrictions on methane, and a carbon-dioxide and methane case with restrictions on methane. Methane proved to be responsible for a large share of the reductions. Reilly closed with several conclusions. First, the costs among countries are far different with equal percentage reductions and methane included than under Kyoto targets and with carbon dioxide only. Second, methane emissions and the ability to reduce them is a critical factor, especially in developing countries.

Cho Gyeong Lyeob – Global Impact of the Kyoto Mechanisms: Results from the KEEI CGE Model

Lyeob discussed Korea's Global Trade and Environment Model (GTEM-KOR), which was developed by ABARE (in Australia) and uses both a database and GEMPACK. Version 1.0 of the model is both a global and national CGE Model, which uses MPSGE in GAMS language. After last year's meeting, the Koreans worked with Tom Rutherford at the University of Colorado to develop a modified GTAP, second version of KEEI's computable general equilibrium model in order to have a consistent data set with energy prices and quantities in IEA statistics. A version of the model will soon be available on the internet. Lyeob presented results of three scenarios that allowed for CDM investment, supplementarity up to 50 percent, hot air trading, and transaction costs. Results show that if Korea set a 30 percent reduction target under the Kyoto Protocol, global carbon prices would rise by a modest $4 per ton. However, the welfare effects in some countries, in particular coal exporters to Korea, rise. As for future developments for the model, Lyeob says the group hopes to develop more realistic scenarios, increase greenhouse gas coverage, include sinks and land use components, include more flexible and practical clean development mechanism activities, and incorporate important bottom-up data.

Lei Ming – Integrated Analysis of Energy-Environment-Economy of China Based on Green Input-Output Model

The model presented by Lei from Beijing University is a negative feedback system between human economic activities and nature. In this model, the marginal opportunity cost (MOC) refers to the costs not only related to production, but also to all human activities. So MOC is a sum of marginal production costs (MPC), marginal user costs

(MUC), and marginal environmental costs (MEC). Lei's conclusions and suggestions related to fuel substitution and structural change in the chemical and industrial sectors as well as service sectors. Lei also showed results of a "Green GDP", where approximately 4% of China's GDP is overestimated and caused by exploitation of natural resources.

Fatih Birol – Modeling Energy Sectors in China and East Asia: Findings from IEA's World Energy Outlook-2000

Birol's presentation gave some guidance on how the world energy system will develop over the next 20 years in the reference scenario. He pointed out that fossil fuels will continue to dominate the world energy supply in the next twenty years as growth comes largely from China and India.

According to the IEA analysis, there will be few changes in fuel mix in part because developing countries will account for a larger percentage in the future, so oil increase is expected to offset other changes. But coal will lose some market share to gas. Most incremental oil output after 2010 will come from OPEC, while incremental output from non-OPEC countries falls rapidly after 2010. Birol's gas projections—6 percent of total energy demand in 2020— are low relative to statements from the Chinese government officials. IEA estimates that imported oil will account for three-quarters of all oil demand (11 million barrels per day by 2020, with 2.7 mbd of that from domestic production) unless new measures are taken. In the power sector, Birol predicts that government statements about nuclear power expansion (20 GW by 2010) are similarly overstated. From 1997 to 2020, China will need an average of $22 billion each year for new power generation capacity.

Fatih highlighted three critical issues in China's energy future: (1) investment funds and how they are to be generated; (2) oil import dependence and its relation to oil prices; and (3) local environmental issues and how government considers these in forming energy policy.

Birol also noted that the IEA had been studying recent energy trends in China and initial findings show that total energy consumption has declined by 5 to 8 percent instead of the 15 percent claimed by the Chinese government.

Li Shantong and Zhai Fan– Scenarios for Chinese Economic Development: Top-Down Model

Li and Zhai—long-time and influential participants in these modeling workshops—presented results of different generic economic reform scenarios in China. They used a dynamic CGE model to develop baseline, WTO accession, and service liberalization cases. In the baseline case, the sources of strong growth are high investment, large foreign investment, improvement in total factor productivity, re-allocation of labor from agriculture to industry, and continued opening to the world economy. Average growth is estimated at 6-8 percent between 2000 and 2020, while the population was assumed to peak in 2045 at 1.45 million with a large increase in elderly population (20 percent aged 65 and above).

In the WTO accession scenario, Li and Zhai simulated how tariff reform and quota elimination would impact the economy over the 2001-2008 period. GDP would increase by 1.1 percent by 2005, mostly as a result of agricultural trade liberalization. Also, automobile imports would grow by almost 400 percent, textile imports and exports would both double, and grain imports would increase by 180 percent, although the self-sufficiency ratio would remain above 90 percent.

Similarly, in the service liberalization scenario, GDP would increase as the economy shifts from agricultural to industrial and service sectors with competition, productivity growth in the service sector, and financial investment liberalization in the service sector. Prices would be relatively high indicating supply constraints, but human capacity would be the bottleneck. Ultimately, the service liberalization scenario would yield a 3.9 percent increase in GDP compared to the baseline, so Li emphasized the importance of service liberalization policies, since they would have a greater effect on economic growth and consumer welfare than would WTO accession, where financial liberalization is especially important.

Ron Sands and Jiang Kejun – Update on SGM China

After providing some basic background on the top-down model known as Second-Generation Model (SGM), Sands explained that the model reflects capital stock structure where shorter lead times in response to carbon policies catch capital stocks by surprise and thus raise the marginal abatement costs. SGM-USA has 22 sectors, while other regions are currently being updated and SGM-Brazil has only recently been completed. Abatement costs for China and India are lower than for other Non-Annex I countries because of the heavy coal dependence as well as a disparity between purchasing power parity (PPP) and real exchange rates. Sands summarized future work including improving the baselines, improving technological representations, and justifying substitution elasticities. In the longer term, Sands' group wants to simulate emissions trading, at least among sectors, and make the model modular to allow individual sectors to analyze their own impact.

Tae Yung Jung – Recent Modeling Activities of IGES: The Case of Korea

Jung presented the Greenhouse Gas Emission Model for Asia (GEMA), a country specific hybrid model that addresses investment flows between countries and reflects fuel substitution elasticity effects of different fuels. The model, which links together an open macroeconomic model, an econometric CGE model, an energy and GHG emissions model, and a bottom-up model is used for CDM analysis—project based analysis and bilateral financial flows. Ultimately, Jung emphasized that the model needs to mature, so a variety of future plans were put forward. Among them are plans to collect and incorporate more historical data for China & Korea into the model and better capture economic changes. The rapid structural changes in each of these economies should also be brought into the model.

Session III – Bottom-up Modeling Activities

Kang Seung-Jin – Korea Bottom-Up Model for Energy and Carbon Forecasting

Kang explained that KEEI has two bottom-up models. One is a long-term forecasting model for energy and carbon dioxide and the other is EFOM-ENV, a model developed by multilateral agencies in the 1970s and 1980s. Kang provided an overview of the KEEI model by describing it as an accounting model that projects demand at a disaggregated level. Economic growth, industrial structure, car ownership, home appliances, government plans, and technical progress, and other factors are separately analyzed. There is no macro-economic feedback in model, but energy efficiency is easy to incorporate. In terms of future work, Kang hopes to focus on improving data availability and finding ways to incorporate policies and measures as well as ways to analyze price effects.

Day Two, 24 May

Jayant Sathaye – Hot Air and Cold Water: The Unexpected Decline in China's Energy Consumption

Sathaye discussed the apparent phenomenon in China that energy consumption declined by roughly 10 percent while GDP rose 35 percent between 1996 and 2000, at least according to official Chinese data. Coal output and use have declined by even larger amounts. Sathaye described some of the unintentional, intentional, and uncontrolled factors. Unintentional factors are mainly related to the generic economic reforms, particularly state-owned enterprise reforms. A large number of small, inefficient factories, for example, have closed or merged since 1997 and many SOEs now have incentives to focus on profit rather than just output. Intentional factors include a strong set of policies to encourage energy conservation and the closure of small, dangerous coalmines. Inaccurate statistics are also likely, both in terms of tracking output at coalmines, and recording true growth in GDP. More data on capital turnover needs to be analyzed to determine its role in the diverging energy-economy trends in China. While many observers note that energy statistics are definitely flawed due to unreported coal use, most also note that actual energy use has declined. The global implications of this unprecedented behavior could strengthened if researchers can better understand how the divergence occurred.

Chen Wenying – MARKAL-Macro Applications for China

Chen introduced the China MARKAL model, development of which is being supported by the U.S. Department of Energy. MARKAL is unique in that it includes both fossil and renewable energy sources, six industrial sectors, and a wide variety of technologies within each. The five demand sectors are agriculture, industry, residential, transportation, and commercial. The model assumes that energy consumption will shift away from coal in general, but that coal use will remain common as gasification and liquification replace traditional coal-burning methods. In addition, China's service sector is expected to rise from 31 of economic activity in 1995 to 55 percent in 2050 (with a population of 1.575

billion in 2050). Ultimately, Chen predicts energy consumption in 2050 to be 3,399 million tons of coal equivalent (MTCE) compared to 982 MTCE in 1995[2]. Growth comes largely from the residential and transport sectors, while industrial energy use falls from 70 to 37 percent. Transport jumps from 10 to 26 percent, and residential energy use grows from 13 to 25 percent. A startling finding is that coal falls from 60 to 26 percent of energy consumption. The bottom-line is that carbon dioxide rises from 816 MtC in 1995 to 3021 MtC in 2050, while sulfur dioxide rises to 37.5 MtC.

Gian Carlos Tosato – Recent ETSAP Modeling Activities with Markal-Times

Tosato discussed the International Energy Agency's collaborative effort among fifteen countries to develop modeling tools, improve understanding of energy and environmental systems, and better understand the role of technology in crafting intelligent climate change mitigation policies. This work focused on the Energy Technologies Systems Analysis Project (ETSAP). Most of Tosato's talk was descriptive of the project and how the team of collaborators has worked to improve MARKAL.

Skip Laitner – Modeling a Technology-Based Climate Strategy within an Equilibrium Framework

Laitner's presentation focused on integration of top-down and bottom-up models. The models assume optimal decisions, but inefficiencies are well known. First, he described an advanced scenario for energy use that would bring emissions to 1990 levels by 2020 and introduced the AMIGA model.

AMIGA is a macroeconomic model designed at Argonne National Lab designed to overcome limitations in exiting tools used for energy and economic analysis. It uses 1999 as reference case, and sector output is a function of utilized capital and labor input. Utilized capital is a function of production capital and energy services, while energy savings are a function of energy saving capital and energy input. This model uses a computable general equilibrium approach to model an investment-led climate strategy through 200 sectors that can have a positive economic effect. Under an advanced policy scenario, the model assumes a $50/ton-C tax on carbon, which would lead to a fall in carbon emissions largely due to energy efficiency improvements but also due to fuel switching. Most of the carbon tax is recycled and used to reduce payroll taxes. Emissions would return to the 1990 level by 2020 with most of the reduction occurring in electric utilities and transportation. The industrial sector accounts for about 20 percent of total reduction. Laitner proposes that such a scenario would yield net savings and economic benefits, although several uncertainties could bias results in either direction. Laitner closed by challenging policymakers to consider that the difficulty lies not with the new ideas, but in escaping the old ones, a quote from John Maynard Keynes.

Session IV – The Stanford Energy Modeling Forum (EMF)

[2] One million tons of coal equivalent contains is roughly 29.3 gigajoules of energy.

John Weyant – History and Methodology of the EMF

Weyant's presentation was intended to provide a history of the Energy Modeling Forum (EMF), organized by Stanford University. Weyant described the objectives, design principles, process, studies, examples, contributions and challenges, and a summary of groups that have tried the EMF approach. The essential goal of EMF has been to open channels of communication between modelers and policy-makers. In addition, the EMF combines the efforts of modelers worldwide in order to provide a better understanding of model differences and the strengths and weaknesses of existing models, and to identify high priority areas for development and useful information to incorporate into planning and government policy.

In the first half of the 1970s, policy analysis became important, but not necessarily in the energy sector. Weyant summarized the EMF process of bringing parties, specifically experts, modelers, corporate and policy advisors, IPCC, CEA, corporate affiliates, and government sponsors together to feed information to the EMF working group. Stanford EMF staff also exchange information with working group topic. Weyant described the EMF design principles of broad participation, focus on model comparisons, policy relevance, decentralized analysis, and wide dissemination of results. The core process was described as a series of meetings. For instance, in the first meeting, parties would identify key issues, design initial scenarios, and organize study groups. The goal of the following meetings would be to interpret results and review issues and scenarios. In the next to last meeting, results would be interpreted and an outline of a final report prepared. Finally, the parties review the draft report and review modeler and study group reports in the last meeting.

Weyant presented results of the EMF's most recent studies, whose topics have ranged from carbon emission reduction to identifying markets for energy efficiency. Weyant explained how EMF-16 noted the amount of uncertainty of costs estimated because of uncertainty over the scope of emissions trading and variety of models. The extremes can be explained in part by the degree of macroeconomic adjustment. Weyant concludes that different mitigation costs are largely due to external factors in the models, such as baseline emission and policy regime. The objectives of EMF-19 are to understand how technology and technological change is represented in models and to assess how these assumptions influence results.

Study groups are addressing different scenarios (under different economic and technological conditions), technological characterizations (comprehensive and consistency, levels of aggregation, uncertainty, and timing), and how technological change (invention, innovation, and diffusion) can be modeled. Weyant showed how results depend on the model—for instance emissions range from about 1500 to 6000 million tons of carbon (MTC) in 2100 for China for various models. The reasons for these differences can be divided into external and internal factors. Policy regime, baseline emissions, and benefits of emissions reductions are external, while technology and substitution are internal.

Weyant pointed out that developing countries with only a few models should not be deterred from participating, because the number of participants is not crucial. The role of the EMF is envisioned as that of a spokesperson for the modeling community as well as an unbiased arbiter between parties. However, internal conflict between ecological and economic goals and political manipulation can compromise the group's efforts.

Session V – Integrated Assessment

Ron Sands (for Jae Edmonds and Sonny Kim) – Using Mini-Cam for Burden-Sharing Analysis

Ron Sands gave this presentation for his colleagues Jae Edmonds and Sonny Kim. The presentation underscored the value of burden sharing as a means of stabilizing CO_2 emissions more quickly and at a lower cost. A reference case using the SRES A1G assumptions was presented that yields high CO_2 emissions growth until 2085 (peaking at 27 BTC) before leveling off as China and India play a crucial role in driving the world trends. For the hypothetical protocol, stabilizing carbon dioxide emissions requires U.S. emissions to return to the 1990 level between 2020 and 2050. Sands then explained several burden-sharing options. First among them was a grandfather option, is analogous to the Kyoto Protocol, since it links reductions to a base year level.

The other burden-sharing options were based on equal per-capita GDP of the respective country, historical responsibility, and a mixture where grandfathering is adjusted over time for GDP growth. Regarding emission paths, Sands presented several for both the U.S. and China where the burden-sharing option pursued by each and when they begin is the primary factor dictating the differences in paths: (1) global common carbon tax; (2) historical emissions from 2000 with allocations adjusted for economic growth and all nations participating from the beginning; (3) historical emissions from 2000 with allocations adjusted for economic growth, Annex 1 countries leading, China following in 2020, and other nations following when reaching China's year 2020 income per capita; (4) same as (3) but 2035 set for China instead of 2020; and (5) equal per capita emissions from 2000 and all nations participating from the beginning.

Ultimately, the type and timing of burden-sharing determines which countries would buy and sell tradable permits. For instance, the U.S. is consistently a buyer, but China, although usually a seller, could become a buyer under certain conditions in the future. Sands concludes that CO_2 stabilization at 550 parts per million (ppm) requires advancing the time period for the U.S.

Detlef van Vuuren & Li Yun – Using IMAGE for Integrated Assessment

Van Vuuren's talk focused on the TIMER energy module, part of the larger IMAGE model developed in the Netherlands. First, he presented a chart showing how the population and world economy models can be combined and linked to an energy model—TIMER—and then to environmental as well as impacts modules. TIMER is a system dynamics simulation model with trade as an endogenous variable as well as endogenous learning. In this model, demand is based on structural change as well as autonomous and price-induced changes in energy intensity. Fossil fuel depletion and substitution are included as well. After explaining the model, Vuuren presented learning curves for technology development and discussed different SRES scenarios, including construction of baseline scenarios for China.

Toshihiko Masui and Yang Hongwei – Recent Results from AIM

Masui's talk focused on scenarios for reducing solid waste in Japan. First, Masui gave some background information on the Asian Integrated Assessment Model (AIM), which includes a variety of modules—local, impact, end-use, top-down, material, and trends. AIM Material, for example, is a CGE that links CO_2 reduction with solid waste management through a bottom-up model. AIM Local, on the other hand, shows the side effects of technology combinations on local environments depending on the fuel type & price, technology costs, life-span, respective share of energy output, and service demand. Masui showed that the output variables include environmental effects & costs, technology options, and service output and applied the model to Beijing. Yang followed Masui by talking about the methodology and results from reducing local pollution in Beijing using AIM/LOCAL. Yang's analysis employed a bottom-up optimization model.

Day Three, 25 May

Session VI – Co-Benefit Analysis

Richard Garbaccio – Modeling the Health Benefits of Carbon Emissions Reductions in China

Garbaccio described a health model that values the health effects of urban air pollution from carbon emissions in China and integrates them with a CGE model of the country's economy. The CGE model is a dynamic recursive Solow growth model with 30 sectors (5 energy sectors) using 1995 as the base year. It includes both planned and market sectors of the economy, and recently added natural gas as an energy supply option. The model incorporates a dispersion module to transform local pollution emissions to concentrations, dose-response functions to transform concentrations to health effects, and willingness-to-pay (based on U.S. values and transformed to China based on relative incomes) to value these health effects.

Data summarizing the health effects of air pollution in urban China was presented, ultimately showing that health damages were valued at 5 percent of GDP in 1995 but rising to 13 percent in 2020. Garbaccio then presented a policy simulation for the case of a carbon tax—specifically aimed at a 10 percent reduction in carbon emissions—to show the resulting reduced health effects and economic effects. The impacts from a 13 percent increase in the price of coal (including tax) are a 12 percent reduction in coal use, 6 percent reduction in particulates, 7 percent reduction in premature deaths, and 7 percent reduction in cases of chronic bronchitis. Ultimately, an initial and slight decrease in GDP is offset by later growth deriving from recycled tax revenue that stimulates growth. In terms of ongoing work for his research, Garbaccio hopes to improve the health effects model and endogenize the health effects on labor supply and productivity.

Zhang Xiao and Zheng Yisheng – Climate Change, Health Risk, and Economic Analysis

Zhang showed how to use a bottom-up valuation of climate change damage on human health. Both physical and psychological heat stress, urban air pollution, and other negative effects are included and divided into direct and indirect pathways. Zhang presented charts on the bottom-valuation of both environmental damage (through sulfur oxides and particulates) and climate change damage (scenario-based risk assessment). Direct pathways include heat wave morbidity and mortality and extreme weather health effects, while indirect pathways include extreme weather disasters, air pollution, and sea-level rises. The presentation concluded with discussion of different valuation methodologies. They included gross production and consumption loss, human capital, willingness to pay, and a contingent valuation method. The latter set a value equal to $60,000 per life in Beijing and other major urban areas.

Koen Smekens and Chen Changhong – Using MARKAL as an Analytic Tool for Pollution Control and Energy Policy Options: The Shanghai and Three-Cities' Cases

This presentation by Smekens focused on how MARKAL can be applied to energy and environmental issues, such as technological and fuel standards as well as emission fees and taxes. He showed how MARKAL now has a materials section added to it (similar to AIM), while other options such as MACRO, MICRO, and non-clairvoyant options can be added as well. The model can deal with environmental issues through technology and fuel standards, end of pipe options, externalities, annual caps, and regional caps. Smekens demonstrated an application to Shanghai covering the period 1995-2035, 173 technologies, 30 end use demand categories, and 7 environmental variables (emissions) that yielded several policy options. They include increased use of natural gas from Western China and Siberia, planned gas combined cycle power generation, increased use of low and zero emission power generating technologies (imported from the Three Gorges, limiting coal use, & wind turbine construction), and local air pollution abatement. The results from the model reveal final energy demand, NO_x emissions, power plant capacities, CO_2 emissions, and marginal cost. Smekens pointed out that these costs become greatest for steel production.

Francisco De La Chesnaye – Modeling Non-CO_2 Greenhouse Gas Emissions and Mitigation & the Importance of a Multi-Gas Abatement Strategy

De La Chesnaye emphasized how other greenhouse gases (besides carbon dioxide) should be addressed as a means of reducing abatement costs for greenhouse gas target levels. He suggested focusing on methane—with a 100 year greenhouse warming potential of 21—and technologies to mitigate emissions from specific sources of methane such as landfills, natural gas, coal mining, livestock manure, and ruminant livestock. For China, most methane emissions come from coal mining and rice production. De La Chesnaye also discussed nitrous oxide (N_2O), derived from agricultural soils, automobiles, and industrial applications and has an even higher warming potential at 310. In 1997 and 1998, China emitted 980 million tons of carbon with 78 percent from carbon dioxide and 22 percent from other greenhouse gases.

David Streets – RAINS Asia and Local Applications

Streets' presentation demonstrated how RAINS, which has been used to determine emission reduction levels in Europe, has been applied to Asia to estimate emissions and control costs. In the model, population and economics drive energy forecasts, which in combination with technology and fuel determine emissions. Emissions are also affected by control strategies, which define control costs. From this, meteorology, atmospheric chemistry, and deposition are determined, while geology, vegetation, and damage functions determine ecosystems damage. Each of the model's 94 regions in Asia has a matrix of energy use that determines sulfur output, and the latest version has provinces in China and district level in Japan. Based on his analysis, Streets believes the IPCC SRES scenarios for sulfur emissions in Asia are highly flawed, and that the B1 scenario is likely the most accurate.

Streets presented data on total CO_2 emissions in 2000, including fossil fuels, bio-fuels, cement, and biomass equal to 3,100 million tons CO_2, down from the peak in 1996 of 3,450 (MT). Methane emissions peaked at 39,000 gigagrams (Gg) in 1997 and have since fallen to 35,500 Gg in 2000. He points out that black carbon, which is prevalent in China from coal and bio-fuels, is becoming an increasingly important greenhouse gas—on the scale of methane according to James Hansen of NASA. Due to its potency and the fact that China and India account for about 50 percent of the world's total black carbon emissions, Streets argues that it should therefore receive more attention from policy-makers in China with regard to climate change. The issue is complicated by the fact that haze throughout most of Northeastern Asia, which may be caused by black carbon, cuts radiation reaching the ground by up to 30 percent in the Yangtse region. For more information on RAINS ASIA, see:
http://www.cgrer.uiowa.edu/people/carmichael/acess/emission-data_main.htm.

Session VII – Modeling Project-Based Mechanisms

Hu Xiulian and Jiang Kejun – Perspectives of CDM Collaboration Between Japan and China: A Case Study for the Steel Making Sector

Using the AIM model with 23 sectors, Hu and Jiang showed how CDM would affect the steel sector in China, where 85 percent of production comes from traditional technologies. Steel output is expected to reach 160 million tons by 2030, with most rapid growth coming in the hot rolling process. Pig iron output is flat, and cool rolling and recycled steel are growing steadily. The presenters described three scenarios for the steel industry: (1) frozen technology; (2) market case assuming free competition; and (3) policy case using 100 yuan/t-C and returns used as a subsidy for advanced technology. See the presentation in the appendix for results.

Yang Yufeng – Uncertainty Analysis on CDM Analysis

Yang, from Qinghua University, presented information on a baseline case, leakage data, and a cost-benefit analysis. An uncertainty analysis was performed on a sequestration project, and Yang showed how a CDM project would be different from a normal project in a flowchart. The sources of uncertainty over greenhouse gases derive from fossil fuel carbon dioxide emissions, stationary source emissions of methane and nitrous oxides and mobile source emissions of each of these compounds. Monte Carlo simulation was used to obtain a total uncertainty range, and equations were ultimately used to find uncertainty.

Xu Deying and Zhang Xiaoquan – Potential Impacts of Chinese Forests on the Atmospheric Carbon and Uncertainty Analysis

The objectives of this study, by Xu and Zhang from the Chinese Academy of Sciences, are to describe the F-Carbon model, to estimate carbon sequestration by forestry activities between 1990 and 2050 with both F-Carbon and Comap models, and to compare F-carbon with other models. The results show the historical changes in the forest area in China. From 1973 to 1999, Xu and Zhang show that forested areas went down and then up. Forest cover is estimated to be 26% by 2050, which is up from 19% in 2010.

Jayant Sathaye – COMAP Model (Comprehensive Mitigation Assessment Process)

Sathaye's presentation showed results from the COMAP model including land use scenarios, carbon stocks, costs and benefits, macroeconomic impacts, and a comparison and integration of costs. He explained that future work will look at cost curves, in particular theoretical relative to actual curves based on barriers. Factors such as land tenure, information, markets, credit, legal protection, and rural values will be included in the analysis.

He Juhuang and Xu Songling (presented by Shen Keting) – Analyzing Carbon Emissions Reductions in China with CGE Model

Shen reviewed previous carbon emission studies in China before introducing a computable general equilibrium (CGE) model by He, et al. for China that includes a carbon tax and comparing it to previous studies. Zhang Zhongxiang's model was described as a 10 sector dynamic CGE using 1987 as the base year and assuming full market economy. The model of Richard Garbaccio uses 1992 input-output date and reflects the dual nature of the economy. The model of Ma Gang, Zheng Yuxin, and Fan Mingtai is a 33-sector static model used to analysis aggregate factors. Professor Hu's model is a static model to assess the effects of carbon taxes. Shen provided a description of the model and equations, including carbon taxes, and explained that a dynamic model is under development. They found that the carbon tax would have a more severe effect on coal production than other options, while the effect on investment would be significant although effect on GDP would be small. A 10% reduction in emissions raises coal prices by 20%. Comparisons of their model with previous models revealed differences in magnitude of the effects on coal and oil prices as well as on GDP. These are due, in part, to different allocations of labor and capital within the models.

Session VIII - Discussion of Next Steps

General conclusions were that the workshop helped participants exchange a wealth of information and that we moved forward with our goal of helping developing countries build technical capacity for more detailed climate policy analysis. Most participants voiced strong support for a workshop next year.

Several participants suggested that our presentation methodology should encourage more streamlining as there is too much time spent introducing models. Consistent documentation across models will give more efficiency. During the next workshop, presenters could use a template of information on their model and spend more time discussing assumptions and results and less introducing the model.

China's Energy Research Institute has agreed to begin a model comparison activity based on a simplified EMF approach. Outstanding questions include whether the comparison will be regional or China only, and whether international experts will participate.

Representatives from the Korean Energy Economics Institute found the workshop very helpful and stated that they would also consider a domestic comparison of models in Korea. Other universities and research institutes would need to be contacted.

Other suggestions:

- Prices are important, but not the only policy option to consider thing. Other considerations include: transaction costs, risk and uncertainty, double-dividends, R&D, and the role and value of information. Look at other options besides just carbon taxes.

- Organize the meetings around topical subjects such as co-benefits or integrated assessment impacts, rather than a particular model. Or look at just one issue, like IA or health valuation. Make better use of electronic communication. Would it be possible to establishing 4 or 5 subgroups and let them focus on their own issues?

- Suggestion for China or Korea EMF-type strategy: Korea: Establish 3 types of modeling groups. Bottom-up modelers within countries. Chinese or Korean top-down models. Global models with China or Korea as a region.

To be sustainable, modeling groups need to get more personal benefits. Exposure to new approaches, immediate expert review, peer recognition, and publications are issues to consider.

Appendix A - List of Attendees

China-Korea-U.S. Economic and Environmental Modeling Workshop
Oriental Garden Hotel, Beijing, China
23-25 May 2001

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Appendix B - Workshop Agenda

China-Korea-U.S. Economic and Environmental Modeling Workshop

Beijing, China
23-25 May 2001

<u>Wednesday, 23 May 2001</u>

8:30-9:00 Registration
9:00-9:15 Welcoming Remarks, Zhou Dadi, Energy Research Institute

Session I: Introductory Remarks

9:15-9:30 China, Jiang Kejun (ERI)

9:30-9:45 Korea, Jae Kyu Lim (KEEI)

9:45-10:00 United States, Paul Schwengels and Chris Botnick (EPA)

10:00-10:15 Break

Note: Speakers should plan their talks to last 25 minutes, with 5 minutes for questions.

Session II: Top-Down Macroeconomic Models

10:15-10:45 MIT’s CGE Model, John Reilly (MIT)

10:45-11:15 Chinese Economic/Environmental Top-Down Model, Li Shantong (State Council Development Research Center)

11:15-11:45 Discussion

11:45-12:15 Global Impacts of the Kyoto Mechanisms: Results from the KEEI CGE Model, Cho Gyeong Lyeob (KEEI)

12:15-12:30 Discussion

12:30-14:00 Working Lunch

14:00-14:30 Integrated Analysis of Energy-Environment-Economy of China Based on Green Input-Output Model, Lei Ming (Beijing University)

14:30-15:00 Modeling Energy Sectors in China and East Asia: Findings from IEA's World Energy Outlook-2000, Birol Fatih (IEA)

15:00-15:30 An Update on SGM China, Jiang Kejun (ERI) and Ron Sands (PNNL)

15:30-16:00 Recent Modeling Activities of IGES: The Case of Korea (GEMA-K), Tae Yong Jung (IGES)

16:00-16:30 Discussion/Break

Session III: Bottom-Up Technology Models

16:30-17:00 China Carbon Forecasting Using LEAP 2000, Guo Yuan (ERI)

17:00-17:30 Korea Bottom-up Model for Energy and Carbon Forecasting, Kang Seung-jin (KEEI)

17:30-18:00 Discussion/Wrap-Up

<u>Thursday, 24 May</u>

Session III (Continued): Bottom-Up Technology Models

9:00-9:30 Methodology for Estimating Costs in Carbon Mitigation in Forestry and Energy Sectors: A Bottom-Up Approach, Jayant Sathaye (Lawrence Berkeley National Lab)

9:30-10:00 Markal-MACRO Applications for China, Chen Wenying, (Qinghua University)

10:00-10:15 Discussion

10:15-10:30 Break

10:30-11:00 Summary of IEA Modeling Activities, Gian Carlo Tosato and Koen Smekens (IEA)

11:00-11:30 Modeling a Technology-Based Climate Strategy within an Equilibrium Framework, Skip Laitner (EPA)

11:30-12:00 Discussion

12:00-13:30 Working Lunch

Session IV: The Stanford Energy Modeling Forum

13:30-14:15 History and Methodology of the EMF, John Weyant (Stanford)

14:15-14:30 Discussion

14:30-15:15 Panel Discussion on Using an EMF-type of Methodology in China and Korea, John Weyant (Stanford), Jae Kyu Lim (KEEI), Zhang Aling (Qinghua), and Jiang Kejun (ERI), Tae Yong Jung (IGES)

15:15-15:30 Break

Session V: Integrated Assessment

15:30-16:00 Using Mini-Cam for Burden-Sharing Analysis, Jae Edmonds and Sonny Kim (PNNL)

16:00-16:30 Using IMAGE for Integrated Assessment, Dr. Detlef (RIVM, Netherlands)

16:30-17:00 Results from AIM, Masui, NEIS (Japan)

17:00-17:45 Discussion/Wrap-Up

<u>Friday, 25 May</u>

Session VI: Co-Benefit Analysis

9:00-9:30 Economic Evaluation of Environment Damage in China, Zhang Xiao (CASS)

9:30-10:00 Modeling the Health Benefits of Carbon Emissions Reductions in China, Richard Garbaccio (EPA)

10:00-10:30 Discussion/Break

10:30-11:00 Modeling Other Gases, Francisco De La Chesnaye (EPA)

11:00-11:30 RAINS ASIA and Local Applications, David Streets (Argonne National Lab) and Chen Changhong, Shanghai Academy of Environmental Sciences

11:30-12:00 Discussion

12:00-14:00 Working Lunch

Session VII: Modeling Project-Based Market Mechanisms

14:00-14:30 Perspective of CDM Collaboration Between Japan and China: A Case Study for Steel Making Sector, Hu Xiulian (ERI)

14:30-15:00 Uncertainty Analysis on CDM Methodology, Yang Yufeng (Qinghua University)

15:00-15:30 Forestry Analysis, Zhang Xiaoquan (Chinese Academy of Forestry)

15:30-16:00 Discussion

16:00-16:30 Break

Session VIII: Defining Future Activities

16:30-17:00 Summary and Finalizing Future Activities

17:00-17:30 Wrap Up and Conclusions

Appendix C - Presentation Material

1. Seung Jick Yoo – Introductory Remarks from Korea Energy Economics Institute
2. John Reilly – MIT's Emission Prediction and Policy Analysis Model
3. Cho Gyeong Lyeob – Global Impact of the Kyoto Mechanisms: Results from the KEEI CGE Model
4. Fatih Birol – Modeling Energy Sectors in China and East Asia: Findings from IEA's World Energy Outlook 2000
5. Li Shantong and Zhai Fan– Scenarios for Chinese Economic Development: Top-Down Model
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7. Tae Yung Jung – Recent Modeling Activities of IGES: The Case of Korea
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9. Jayant Sathaye – Hot Air and Cold Water: The Unexpected Decline in China's Energy Consumption
10. Chen Wenying – Markal-Macro Applications for China
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13. John Weyant – History and Methodology of the EMF
14. Ron Sands (for Jae Edmonds and Sonny Kim) – Using Mini-Cam for Burden-Sharing Analysis
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17. Richard Garbaccio – Modeling the Health Benefits of Carbon Emissions Reductions in China
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19. Koen Smekens and Chen Changhong – Using Markal as an Analytic Tool for Pollution Control and Energy Policy Options: The Shanghai and Three-Cities' Cases
20. Francisco De La Chesnaye – Modeling non-CO_2 Greenhouse Gas Emissions and Mitigation & the Importance of a Multi-gas Abatement Strategy
21. David Streets – RAINS Asia and Local Applications
22. Hu Xiulian and Jiang Kejun – Perspectives of CDM Collaboration Between Japan and China: A Case Study for the Steel Making Sector
23. Yang Yufeng – Uncertainty Analysis on CDM Analysis
24. Xu Deying and Zhang Xiaoquan – Potential Impacts of Chinese Forests on the Atmospheric Carbon and Uncertainty Analysis
25. Jayant Sathaye – COMAP Model (Comprehensive Mitigation Assessment Process)
26. He Juhuang and Xu Songling (presented by Shen Keting) – Analyzing Carbon Emissions Reductions in China with CGE Model