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1st Brazil-U.S. Economic and Environmental Modeling Workshop

Proceedings

Rio de Janeiro, Brazil

19-20 March 2001

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Acknowledgments

This publication documents the 1st Brazil-U.S. Economic and Environmental Modeling Workshop held in Rio de Janeiro on 19-20 March 2001. The workshop brought together over 25 modeling experts from Brazil and the United States to review existing tools, identify future opportunities, and build ties among modelers in both countries.

The workshop was made possible through support from the U.S. Environmental Protection Agency (EPA) and the Federal University of Rio de Janeiro. Paul Schwengels and Michael Shelby lead EPA's efforts to improve cooperation between Brazilian and U.S. modeling experts. Richard Garbaccio, Francisco de la Chesnaye, Skip Laitner, and Chris Botnick provide additional support for the EPA.

The Energy Planning Program of the Federal University of Rio de Janeiro (COPPE) made all arrangements in Brazil for the workshop. Roberto Schaeffer of COPPE organized speakers on the Brazilian side and arranged logistics for the visiting U.S. team. Colleagues of Schaeffer deserve our thanks in helping to make sure the workshop ran smoothly.

Jeff Logan organized the participation of experts from the United States and helped plan the agenda. Karen King, Paulette Wright, and Jay Wertenberger organized contractual and administrative details that made the workshop possible. Meredydd Evans and Tom Secrest reviewed earlier versions of this document.

We would especially like to thank the experts who gave presentations at the workshop. Their presentations generated excellent discussions and helped make 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 between Brazil and the United States.

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Foreword

Energy Planning Program, Federal University of Rio de Janeiro
Brazil and the United States have a long time tradition of cooperation in the areas of science and technology. This historic cooperation has allowed significant advances in various fields of knowledge in both countries.

This publication, which documents the 1st Brazil-U.S. Economic and Environmental Modeling Workshop, reinforces this avenue of cooperation between these two countries by putting together the experience of scientists from Brazil and the U.S. in the field of economic and environmental modeling. Although important advancements have been made in this field in both countries in recent years, a lot remains to be done in order to help understand and address the important and challenging environmental problems associated with energy use and economic development.

In this sense, this initiative, which we sincerely hope is the first of a series of future collaborative efforts between scientist of these two nations, comes at the right moment, when climate change and sustainable development issues are, more and more, part of everyday life, and as such in serious need of state-of-the -art analytic tools and approaches to help solve the challenges that they bring with them.

Brazil, in the field of energy and climate change at least, is increasingly seen as a leading nation in the developing world. But this position of leadership does not come by chance. Scientists in Brazil have always recognized the principle of common but differentiated responsibilities with respect of global climate change, and this has lead Brazil to invest in scientific and technology development in this area.

Climate is a growing and important issue in Brazil, and the number of Brazilian scientists that are, more and more, redirecting their research efforts to this important area is also increasing fast. And in this respect, we are proud to say that the Energy Planning Program, COPPE, Federal University of Rio de Janeiro, is a lead group of scientists in this field in the country, with a long tradition of important contributions to the international scientific literature. The quality and diversity of the presentation in this document, from both Brazilian and U.S. scientists, is a living proof of the great progresses both countries have made already in this area, but is also and indication that a lot more is still in need to be done.

On behalf of the Federal University of Rio de Janeiro and the Brazilian Government, I would like to thank the U.S. Protection Agency for the co-sponsorship of this workshop, thank my colleagues from the Pacific Northwest National Laboratory for the help in organizing it, and also, and more important, thank all of the participants from both countries for their excellent presentations, all essential for the success of the workshop. I sincerely look forward for future cooperation between Brazilian and U.S. scientists is this area of modeling economic development and the environment.

Roberto Schaeffer
Associate Professor, Energy Planning Program, COPPE
Federal University of Rio de Janeiro

United States Environmental Protection Agency

I am pleased to report on a new avenue of cooperation between the United States and Brazil on modeling of economic development and protection of the local and global environment. This document provides a record of the first of what I hope will be a series of meetings, joint activities, and products under a Brazil-U.S. program on economic and environmental modeling.

The United States Environmental Protection Agency and other U.S. agencies have been collaborating with Brazilian agencies for over a decade to help understand and address the environmental problems associated with economic development. This cooperation has become more significant and detailed over time. The joint development and application of state-of-the-art analytic tools and approaches for integrating environmental improvement into sustainable economic development policy is a powerful and needed addition to this cooperation. Both countries stand to learn and benefit by working together.

Over the past several years, the U.S. Government and other institutions have invested major human and financial resources to analyze the economic implications of alternative policies for responding to domestic and global environmental concerns. In the climate change area, economic modeling and analysis have played an important role in development of U.S. policy. In the process, U.S. analysts and policymakers have learned a number of valuable lessons. The complexity of this policy issue has required a range of analytic tools including top-down economic and bottom-up technology-rich models at national, regional, sectorial, and international scales.

These analyses have demonstrated that realistic targets and timetables, consistent with economic decision making and capital turnover horizons, and including flexibility measures, can substantially reduce costs and enhance political feasibility of needed climate actions. They have also illustrated the global nature of the problem and the benefits of global cooperation in the solutions. These analytic tools are beginning to address the role of technological change in determining the levels and types of economic activity, energy use, and pollution in the medium to long term, and to illustrate the importance of technology policies in reducing long-term economic impacts. Economic models with other tools have also been used to quantify the relationships between strategies that reduce greenhouse gases and produce “ancillary” reductions in other pollution burdens, public health, and economic impacts.

All of these results have contributed to the identification of policy options that can achieve environmental goals efficiently and effectively, consistent with continued economic growth. This is, in fact, part of a larger trend in environmental policy in the U.S. and around the world—the movement toward integrating environmental goals into basic policy and economic activity through market mechanisms and other innovative pollution prevention incentives.

Economic, energy, and environmental modeling will become increasingly important in Brazil as market reforms continue to reshape the economy. Policymakers will need realistic models to explore energy and climate change policy options and to minimize total costs. As demonstrated in this workshop, Brazil has made tremendous progress in building models to analyze energy, environmental, and climate issues, and a number of U.S. modeling groups are working with Brazilian colleagues to further this development. Nonetheless, the workshop has also shown that

more work is needed to capture accurately the unique characteristics of Brazil's economy while accounting for international flows of capital and technology.

While the U.S. Government clearly recognizes the need for Brazil to carry out its policy development and decision-making independently, continued collaboration on the development of methods, databases, models, and other analytic tools can provide better information, and better inform policymakers in both countries. The U.S. Environmental Protection Agency in cooperation with other U.S. Government and non-governmental partners will continue to work with the Federal University of Rio de Janeiro, other research organizations and the Brazilian government to help address these technical and analytic needs.

I am greatly impressed with the quality and diversity of the presentations and the progress that has been made in this first workshop. On behalf of the U.S. Environmental Protection Agency and the U.S. Government, I would like to thank all of the participants in both countries for their efforts, and encourage them to continue and expand the work. In particular, our thanks go out to the Federal University of Rio de Janeiro for co-sponsoring the workshop. I look forward to future joint products with great interest.

Paul Stolpman
Director, Office of Atmospheric Programs
U.S. Environmental Protection Agency

Contents

Overview

Brazil plays an important role in the United Nations' Framework Convention on Climate Change (UNFCCC) due to its large population, huge tropical rainforests, and rapidly growing energy sector. It is an influential member of the Non-Annex I countries and sets an important example for other developing countries.

Per capita greenhouse gas emissions in Brazil are low—about one-fourth the value in the U.S.—due to the country's heavy reliance on hydropower and other renewable energy sources as well as much lower per capita energy use (See Figure 1). Currently, carbon dioxide emissions associated with deforestation in the Amazon are the largest source of greenhouse gas emissions, although there is considerable uncertainty in tracking these emissions.

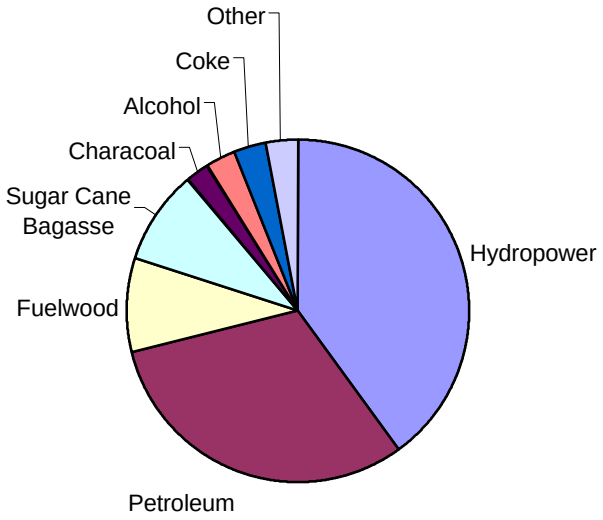

Figure 1 – Primary Energy Consumption in Brazil, 1998
Source: Schaeffer, R. et.al. 2000. "Global Climate Change and Developing Countries: Electric Power Options in Brazil," Pew Center on Global Climate Change, Arlington, VA.

Brazil is currently privatizing many state-owned energy companies resulting in a shift toward greater fossil fuel use (a shift prompted by having to take cost into consideration when building hydroelectric plants, which had formerly been subsidized). Natural gas, for example, is expected to play a dominant role in new power generation facilities built in the future.

In 1994, Brazilian greenhouse gas emissions were estimated at 137 million tons of carbon equivalent (MtC), with 57 percent from carbon dioxide, 42 percent from methane, and 2 percent from nitrous oxide. Increased carbon dioxide concentrations as a result of deforestation in the Amazon adds an additional 150 to 300 MtC to the atmosphere each year. For comparison, in 1998 the United States released 1834 MtC, with 81 percent from carbon dioxide, 10 percent from methane, 7 percent from nitrous oxide, and 2 percent from a combination of other gases.

Brazil has made remarkable progress in stabilizing its economy after its currency, the *real*, crashed in the aftershocks of the Asian financial crisis. Economic growth has exceeded expectations in 1999 and 2000, averaging 4 percent each year. The pace of privatization has slowed somewhat as a result of the currency crisis, but progress is still being made. At the time of our workshop, there was growing concern over the state of Argentina's economy, which had dire implications for Brazil's exports and imports.

Clearly, Brazil will play an important role in the international response to climate management and carbon mitigation. Domestic development policies will influence both its own greenhouse gas emissions and other developing countries that may follow the examples set by Brazil. Industrialized countries may also have a keen interest in cooperating with Brazil on efforts to stabilize global concentrations of greenhouse gases. Collaborating to build realistic analytic tools to simulate policy options is an important first step in making the collaboration fruitful.

List of Workshop Presentations

The following experts made presentations on economic and energy modeling topics:

1. Roberto Schaeffer: Opening Remarks
2. Paul Schwengels and Michael Shelby: U.S. Economic and Environmental Modeling Issues
3. Luiz Gylvan Meira Filho: Energy and Climate Activities in Brazil
4. Carlos Feu Alvim: Brazilian Experience with Top-Down Models
5. Octavio Tourinho: Top-Down CGE Models
6. Ron Sands and Emílio Lebre La Rovere: Update on the Brazilian Module of the Second Generation Model
7. Alan Sanstad: Empirical Studies of Energy and Productivity Trends in Developing Countries
8. Mauricio Tolmasquim: Integrated Energy Planning Model
9. Emílio Lebre La Rovere: Brazilian Experience with Bottom-Up Models
10. Alan Sanstad: Modeling a Technology-Based Climate Strategy within an Equilibrium Framework
11. Luiz Fernando Loureiro Legey: Linking Bottom-Up and Top-Down Models
12. Elisabeth Sherrill: Land Use Patterns, Deforestation in the Brazilian Amazon and Global Effects, A Dynamic Model of Regional Ecological Economics
13. Eustaquio Reis: Carbon Emissions from Amazon Deforestation
14. Paul Schwengels: Forestry Mitigation Potential and Costs
15. Luiz Pinguelli Rosa: Greenhouse Gas Emissions from Hydroelectric Reservoirs
16. Newton Paciornick: The Brazilian National Communication
17. Alexei Sankovski: Methane Marginal Abatement Curves for Major Emitting Countries
18. Roberto Schaeffer: Impacts of Foreign Trade on Energy Use and CO2 Emissions of Brazil, and Energy Consumption and Carbon Emissions from Household Expenditures in Brazil
19. Renaldo Seroa da Motta: Health and Economic Values for Mortality and Morbidity Cases Associated with Air Pollution in Brazil, and Economic Losses Due to Fire in the Amazon
20. Richard Garbaccio: Modeling the Health Effects of Carbon Emissions Reductions, The Case of China

Rapporteur Notes

The following notes summarize presentations made by Brazilian and U.S. modeling experts over the course of two days. Presentation material for many of the speakers is contained in the appendixes.[1]

Workshop Presentations – March 19 (Day One)

Roberto Schaeffer – *Opening Remarks*

Roberto Schaeffer, from the Federal University of Rio de Janeiro (UFRJ), opened the meeting by providing some background information on Brazil's greenhouse gas emissions as well as the country's stance on global climate change negotiations. First, Schaeffer pointed out that the two key drivers of future emissions in Brazil stem from privatization of the power sector and the move away from ethanol-powered cars. While electricity has so far been mainly generated from hydropower, the recent shift towards fossil fuel plants has coincided with the sector's privatization. Although several years ago Brazil developed an ethanol fuel from sugar-cane that is considered a zero net emitter of CO_2, almost no ethanol cars are being produced. Nevertheless, he points out that several studies have been developed in order to relate the emissions of GHG to trade and examine the carbon linkage of production and consumption among countries, as it shall be presented along the workshop.

Regarding climate change negotiations, Schaeffer communicated Brazil's international stand emphasizing that all countries bear responsibility in addressing the climate problem. Brazil believes the mitigation responsibilities should not be separated into developing versus developed country status, but rather historical emissions. According to Schaeffer, one reason these questions may not be being treated as they should is the fact that Brazil is a Non-Annex I country; in other words, it still does not have any specific commitment to reduce Greenhouse Gases (GHG). He added that Brazil was disappointed that the Bush administration announced it would not consider carbon dioxide a pollutant in the power sector despite a previous campaign pledge to the contrary.

Paul Schwengels – *U.S. Economic and Environmental Modeling Issues*

As an introduction, Schwengels presented the primary goals of his EPA office: (1) to develop market mechanisms for pollution and GHG (CO_2) emissions control; (2) to provide policy analysis for the EPA on domestic issues and to assist in negotiation processes; and (3) to integrate environmental strategies with multiple benefits. Schwengels provided several examples with regard to the last point. For instance, his office works with developing countries on climate change issues, especially in areas where technical cooperation can be exchanged. In addition, they develop capacities on clean energy and clean transportation and perform economic modeling in order to help developing countries identify economic issues.

[1] For online color versions of these presentations, please visit PNNL's we page at http://www.pnl.gov/aisu

Schwengels next outlined what he saw as the objective of the workshop: to build a community of experts between Brazil and the U.S. that could address technical issues related to modeling climate change policy actions. In the area of economic modeling, the goals of the EPA in this seminar are to enhance cooperation between Brazil and the United States and thereby to improve methods. The EPA also intends to develop informal opportunities to compare results, discuss cooperation, and share some ongoing experiences with South Korea and China with modelers. Ultimately, the EPA hopes to figure out what is going on in Brazil by gaining a better understanding of key models and ongoing work in both countries.

He noted that he could not speak on behalf of the new administration because it was still in the process of forming its climate policy. Material from this presentation is reproduced in Appendix C-1.

Michael Shelby – *U.S. Economic and Environmental Modeling Issues*

Shelby's presentation focused on the overarching goals of U.S. economic modeling activities. He outlined reasons for the U.S. goal of "when", "where", and "what" flexibility in mitigating emissions, and why it views collaboration with Brazilian experts as an important objective. Specifically, Shelby emphasized the cost reductions of expanding the targets over a longer time-period, addressing other greenhouse gases besides CO_2, and seeking reductions throughout the world by means of international trading and Clean Development Mechanisms. In addition, Brazilian policy relating to its huge forestry resources and the country's leading role in the Non-Annex I group were noted as key points. Material from this presentation is reproduced in Appendix C-1.

Luiz Gylvan– *Energy and Climate Activities in Brazil*

Gylvan, the president of the Brazilian Space Agency (equivalent to NASA), focused mainly on scientific and negotiating issues rather than technical modeling points. In expressing his opinion on 'supplementary mitigation', he emphasized that experts have been developing some wrong assumptions with regard to lower mitigation costs for developing countries such as Brazil in targeting CO_2 and other greenhouse gas emissions. According to Gylvan, some recent experiences and studies show that costs are international and will be expensive even in Brazil. On the issue of responsibility for mitigation, Gylvan expressed his belief that time dependence of emissions for each individual country should be considered before assigning individual country targets. Next, he launched into a discussion of non-linearities in the carbon cycle and how this creates difficulties in forecasting temperature changes. The presentation was concluded with a discussion of national cost curves for carbon mitigation and Brazil's policy that each country should mitigate commensurate to its share of the entire costs.

Carlos Feu Alvim – *Brazilian Experience with Top-Down Models*

Feu Alvim presented a macro-model linking an energy matrix to an emission matrix in order to predict GHG emissions from macroeconomic data. In his opinion, the energy matrix, which relates energy intensity with economic activity, is an important instrument for energy policy, identifying strategic inputs into the economy. The energy matrix was built by means of a macro-economic module that gives the GNP, a sectorial module that gives the sectorial products, and an equivalent energy module that outputs the production energy intensities in terms of "equivalent energy". These modules' results are combined in order to estimate energy demand in terms of equivalent energy. The equilibrium between energy demand and supply in physical units can thus be calculated. Emissions are given through the results of final energy demand, conversion coefficients, and emissions coefficients obtained through the macroeconomic and the sectorial modules. Feu Alvim demonstrated that two kinds of hypothesis are very important to his macroeconomic model: capital-output ratio and "domestic" saving. He concluded his presentation by emphasizing that it is very important to try to link the energy sector to the economy as a whole. It is easy to simulate the energy sector even if economic growth is high when there is no feedback, but this is limited as the limits of growth are unknown. Material from this presentation is reproduced in Appendix C-2.

Octavio Tourinho – *Top-Down CGE Models*

The Institute for Applied Economics (IPEA) has a top-down computable general equilibrium (CGE) model that has replaced input-output models for use in analyzing climate change policies. Tourinho introduced several types of CGE that differ in terms of what variables are endogenous and exogenous and what type of firm behavior is assumed. The models can also differ in levels of sophistication as to what costs are included and what assumptions are made.

Tourinho described the advantage of CGE models as not only their ability to demonstrate circularity, but that they also show the agents' behavior. For these reasons IPEA has been developing a CGE model in order to analyze the burden of CO_2 emissions distributed amongst the several economic sectors, to evaluate the possibilities to control these emissions through taxes, and to see the effects of trade liberalization. To date, the model is used to simulate carbon dioxide emissions and does not cover other gases. The model covers 39 sectors, with 28 of them industrial and 2 transport. The model is calibrated to 1998 data. Tourinho described the model but did not give any results from the model runs. Material from this presentation is reproduced in Appendix C-3.

Ron Sands and Emílio Lebre La Rovere– *Update on the Brazilian Module of the Second Generation Model*

Sands started the presentation by presenting some general features of the Second Generation Model (SGM), which groups countries as Annex 1 and Non-Annex 1 as defined by the FCCC (Framework Convention on Climate Change). Seven countries or regions are divided into the Annex 1 group, while the Non-Annex 1 group is represented by seven developing countries or regions. The recent version of the model separates some important sectors such as energy intensity industries (paper and pulp, chemicals,

cement, primary metals, etc.), two different kinds of transportation (passenger and cargo freight), and five agriculture sub-sectors (grains and oil crops, animal products, forest, biomass and others). It is important to specify some agriculture sub-sectors due to the fact that land use impacts climate change. Before Kyoto, Sands had done some simulations in order to estimate the cost of mitigating U.S. carbon emissions over the medium-term. Three scenarios were analysed. The first one supposed the 1990 emissions target, the second one the 1990 level plus 10%, and the latter the 1990 level minus 10%. He verified that mitigation costs are very low in the 1990 (+10%) scenario in relation to the other scenarios and concluded that the issue of flexibility is very important to the U.S. economy. Finally, he presented the objectives of some Energy Modelling Forums (EMF), including ones that focused on stabilizing the atmospheric impacts of Annex 1 country actions on non-Annex 1 countries. Material from this presentation is reproduced in Appendix C-4.

Emílio Lebre La Rovere presented more specific information about recent updates to the Brazilian module of the SGM. His presentation is reproduced in Appendix C-5.

Alan Sanstad – *Empirical Studies of Energy and Productivity Trends in Developing Countries* (with Skip Laitner)

Sanstad's presentation was based on estimation of productivity trends and elasticities for India, Korea, and Brazil. Only manufacturing sectors (for which data are more easily available) were considered in the model. Manufacturing sectors are aggregated into two groups:

- Aggregate manufacturing
- Energy intensity industries

All sectors in the model are represented by a translog production function. For an econometric analysis the model relies on time series data on output from each sector, and inputs aggregated as labor (L), energy (E), materials (M), and investments.

Results presented include the cost shares of four inputs by each manufacturing sector, the technical change biases specifying if a sector saves or uses each input along time and the interfactor relationships, in which the inputs are coupled to show the patterns of substitutability and complementarity.

In his opinion, translog production functions are more realistic than CES functions as employed by the SGM model because translog specifies one elasticity of substitution by each couple of production factors (inputs), while the same elasticity of substitution is employed to all inputs in a CES function. He presented the elasticity of substitution for five Brazilian manufacturing sectors.

Questions remaining to be answered include: Do econometric estimates represent elasticity values that are short or long run or something in between? Is the role of historical estimates important for the long run future projections? Does the assumption of perfect competition really make sense? And how does one resolve the problem of CES production structures containing a limited number of independent elasticity parameters

compared to the translog functions? Sanstad's presentation is reproduced in Appendix C-6.

Mauricio Tolmasquim – *Integrated Energy Planning Model*

Tolmasquim discussed the university's most prominent bottom-up model. The integrated energy planning model has six energy consumption sectors and five energy supply sectors (refineries, natural gas, electricity, coke, and charcoal). Consumption and transformation sectors are sized separately. Tolmasquim presented results from three scenarios that differed according to assumed levels of economic growth (ranging from 3.8 to 5.6 percent).

Emílio Lebre La Rovere – *Brazilian Experience with Bottom-Up Models*

La Rovere presented his work using the Technology Optimisation Model (TOM), a bottom-up type model derived from Markal and built in the 1980s. He presented some data on the Brazilian energy sector in 1970 and 1990, as well as CO_2 emissions estimates. Two scenarios were elaborated for the energy sector for 2010 and 2025: Global reference and Abatement. The first one supposes no autonomous energy intensity improvements and the other allows for some energy efficiency and structural changes in the energy sector.

Alan Sanstad – *Modeling a Technology-Based Climate Strategy within an Equilibrium Framework* (with Skip Laitner)

In general, Sanstad believes there are three paths to reduce greenhouse gas emissions: (1) the trading path, which has more interest among analysts; (2) the technology path, which may offer larger domestic benefits; and (3) the optimal path, which would be a mix of policies, tax shift and/or price changes. Nevertheless, he points out that the optimal one is in fact a mix of the two. With this view established, Sanstad discussed four issues in this talk: the top-down/bottom-up debate, the recently published Clean Energy Futures study, a sketch of the AMIGA model (a modular integrated general equilibrium analysis tool), and results from AMIGA applied to the Clean Energy Futures (CEF) study. The CEF study was done to address criticism of the "Five Lab Study". The study used the AMIGA model to simulate three scenarios of future greenhouse gas emissions in the U.S. AMIGA is a general equilibrium model designed to incorporate key elements of the "bottom-up" perspective. The model allows for reference equilibrium inside of production frontier, providing a more realistic picture of efficiency options. This presentation by Sanstad is reproduced in Appendix C-7.

Luis Fernando Loureiro Legey – *Linking Bottom-Up and Top-Down Models*

Legey presented a comprehensive analysis of the TARGET model, a hybrid model to deal with the merging of Bottom-up and Top-Down Models. As an introduction, he developed the concept of uncertainty, the definition of a complex system, and the principle of incompatibility. He also pointed out the difficulties in working with

statistical data. His enthusiasm for the TARGET model was evidenced by the fact that the model is more "accurate" about the problem of uncertainty and that the model approaches problems from an interdisciplinary point of view. Presentation materials can be found in Appendix C-8.

Workshop Presentations – March 20 (Day Two)

Elisabeth Sherrill – *Land Use Patterns, Deforestation in the Brazilian Amazon and Global Effects: A Dynamic Model of Regional Ecological Economics*

Sherrill created a systems dynamics model (using STELLA) as part of her doctoral dissertation to simulate the process of deforestation in the Amazon and the associated impacts on greenhouse gas emissions. The model has four sectors: land use, projects, population/employment, and ecology. Sherrill described the complex feedbacks within and between each sector. For example, the impacts of settlers in the Amazon area depend heavily on what they are doing. If involved in projects, they have less impact than if engaged in agriculture. She strongly recommended that settlers be given long-term employment, rather than just agricultural plots. The model estimates that carbon released from deforestation will reach a maximum in 2075 at 768 million tons of carbon, about forty percent of all current U.S. GHG emissions. Her presentation is reproduced in Appendix C-9.

Eustaquio Reis – *Carbon Emissions from Amazon Deforestation*

Reis described a prototype model Amazon deforestation that includes interactions between population dynamics and agropastoral land use. He noted that growth patterns in the 1970s were unsustainable, but the rate of deforestation slowed during the 1990s. Road building is a major cause of deforestation. Increased land prices acted as deterrents to further exploitation. Reis presented data showing that Brazil's annual growth rate of deforestation declined from 9.4 percent in 1988 to 3.9 percent in 1998, with the corresponding carbon dioxide emissions falling from a range of 310-450 million tons to 240-350 million tons.

Paul Schwengels – *Forestry Mitigation Potential and Costs*

Schwengels discussed the Tropical Forestry and Global Climate Change Research Network effort funded by EPA. The network includes Brazil, China, India, Indonesia, Philippines, Tanzania, and Mexico. Schwengels' presentation was based on the importance of carbon sinks to developing countries, where mitigation of land use change (the highest percentage of total GHG emissions) yields co-benefits such as rural employment and soil conservation. The COMAP model – a bottom-up approach – is useful for analyzing carbon stock changes, costs and benefits, and revenues. Future work includes estimating CDM potential and barriers and project specific analysis of forestry mitigation options. Another model, FORCLIMIT, was being used to evaluate a case study to better understand key land-use, land-use change, and forestry (LULUCF) issues about leakage and permanence. The approach of his group's work with LBNL is based

on land use scenarios, carbon stock, cost-benefit analysis, and the estimation of macroeconomic impacts. Schwengel's presentation material is reproduced in Appendix C-9A.

Luiz Pinguelli Rosa – *Greenhouse Gas Emissions from Hydroelectric Reservoirs*

Rosa presented data comparing greenhouse gas emissions from a typical thermal plant to those, specifically methane, from hydroelectric dams. These emissions result both from decomposition of submerged biomass (methane) and other, largely unknown, sources (carbon dioxide). Rosa and his team have tried to measure emissions of methane and carbon dioxide from a cross-section of dams in Brazil by means of a simple differential equation on flux of methane in a cube of water. The study has revealed that the depth of the dam reservoir is strongly correlated with the level of methane emissions. Also, carbon dioxide emissions surprisingly seem to be higher than those of methane. Although the study has been handicapped by lack of funds needed to do a full sampling, Rosa emphasized the importance of raising awareness on this issue, especially to the IPCC.

Newton Paciornick – *The Brazilian National Communication*

Brazil's National Communication to the UN Framework Convention on Climate Change has not yet been published, so Paciornick, of the Ministry of Science and Technology, limited his talk to a discussion of the methodology of the document. National Communications are a general description of stops taken or envisaged to implement the climate convention as well as an inventory of anthropogenic emissions by sources and removals by sinks. An up-to-date draft of Brazil's National Communication can be found at http://www.mct.gov.br/clima/ingles/comunic/Default.htm. Paciornick's presentation is reproduced in Appendix C-10.

Alexei Sankovski – *Methane Marginal Abatement Curves for Major Emitting Countries* (with Francisco de la Chesnaye)

Sankovski, from ICF Consulting, outlined sources of methane emissions for most of the major emitters across the world and discussed abatement options and costs. Like India, the vast majority of Brazil's methane emissions come from ruminants. Sankovski then discussed EPA's methodology to determine methane marginal abatement curves. He also presented ideas to reduce the costs of meeting the Kyoto Protocol by 60% through the inclusion of mitigation options that take into account not only CO_2 emissions but also methane emissions. According to him, mitigation options such as the changes in growing practices (for rice paddles) and nutritional diets (for ruminants) in some developing countries could be much less expensive to implement than simply reducing CO_2 emissions. Sankovski concluded that Brazil can contribute major scientific understanding to help improve modeling of non-CO_2 gases. This presentation is reproduced in Appendix C-11.

Roberto Schaeffer *– Impacts of Foreign Trade on Energy Use and CO2 Emissions of Brazil, and Energy Consumption and Carbon Emissions from Household Expenditures in Brazil*

Schaeffer gave an overview of work that he and several graduate students recently began to better understand the potential for "leakage" in carbon emissions related to international trade. The hypothesis is that—given a globally binding carbon mitigation regime—multinational companies will move to countries where it is cheapest to produce. One objective of their work is to assess the impacts of foreign commerce on energy use and CO_2 emissions of Brazil for policy purposes through a commodity-by-industry Input-Output (IO) model in hybrid units applied to the Brazilian economy for the year 1995. The IO model tracks total energy and carbon intensity coefficients derived and applied to the exports and imports of Brazil. A general conclusion for IO trade-environment studies is that the more open the economy the larger the impact trade has on a country's figures.

The aim of a second piece of work is to estimate energy consumption and carbon emissions by household income level in Brazil, in order to examine the interaction between environmental policy (mostly related to energy consumption and climate change) and income distribution. One of the main results of this work until now is the energy and labour intensity tendency according to expenditure in Brazil and compared to several other countries such as Australia, Denmark, the U.S., and the Netherlands. Another interesting evaluation is the study of the explanatory variables for household energy consumption in Brazil through a multivariate regression. This presentation is reproduced in Appendix C-12.

Renaldo Seroa da Motta – *Health and Economic Values for Mortality and Morbidity Cases Associated with Air Pollution in Brazil* and *The Economic Costs of Fire in the Amazon*

Seroa described three approaches to valuing the economic impacts of air pollution: human capital (foregone output), benefit transfer function, and hedonic property price. Foregone output methodology provides the lowest health benefit values associated with air pollution, followed by hedonic, and then transfer pricing. Values of human life using the three methodologies range from $72,000 to $2,000,000. The presentation generated great interest and lively discussion afterwards. This presentation is reproduced in Appendix C-13.

In his second presentation, Seroa attempted to provide estimates of the economic costs of fire in the Amazon. Farmers have traditionally set fires as a way to clear land for planting, but they often get out of control and cause severe damage. Total costs can reach close to $1 billion each year due to loss of assets (animals killed, fences burned, etc.), carbon lost, and human health damage. Farmers who clear land this way are often not aware of all the damage they are causing or the impact on their own income. This presentation is reproduced in Appendix C-14.

Richard Garbaccio – *Modeling the Health Effects of Carbon Emissions Reductions: The Case of China*

Garbaccio described the computable general equilibrium model of the Chinese economy that he, Dale Jorgenson, and Mun Ho created at Harvard University. The model is unique in that it captures both the centrally planned and market-oriented components of the economy. The model uses a 50-year, dynamic Solow growth simulation period that tracks 30 sectors of the economy and five energy sectors.

Recent improvements to the model track the health and economic impacts of local pollution in China. A model of the health effects of fossil fuel use (constructed by the World Bank) is integrated with the economic model. Outputs include both effects on human health and valuation of damages. Results indicate that by reducing carbon dioxide emissions by 10 percent by 2010, coal prices would increase 13 percent leading to a 12 percent reduction in coal use and 7 percent reduction in premature deaths. Garbaccio's presentation is reproduced in Appendix C-15.

Appendix A

Brazil-U.S. Economic and Environmental Modeling Workshop Design Agenda[2]

19-20 March 2001

Co-sponsored by the
Energy Planning Program, COPPE/UFRJ
U.S. Environmental Protection Agency
Pacific Northwest National Laboratory

Marina Palace Hotel, Rio de Janeiro, Brazil

Monday, 19 March 2001

8:00-8:45	Registration
8:45-9:00	Welcoming Remarks, Luiz P. Rosa and Roberto Schaeffer, Federal University of Rio de Janeiro, Graduate School of Engineering (COPPE/UFRJ)
Session I	**Overview Presentations**
9:00-9:30	Energy and Climate Activities in Brazil, Luiz Gylvan M. Filho, Brazilian Space Agency (AEB)
9:30-10:00	U.S. Economic and Environmental Modeling Issues, Paul Schwengels and Michael Shelby, U.S. Environmental Protection Agency (EPA)
10:00-10:30	Question and Answers/Break
Session II	**Top Down Economic Models**
10:30-11:15	The Brazilian Experience with Top-Down Models, Carlos Feu Alvim, ABACC, and Otávio Tourinho, Institute of Applied Economic Research (IPEA)
11:15-12:00	Update on the Brazilian Module of the Second Generation Model, Emílio Lebre La Rovere, (COPPE/UFRJ), and Ron Sands, Pacific Northwest National Laboratory (PNNL)
12:00-12:30	Comments and Discussion
12:30-14:00	Working Lunch

[2] The actual agenda followed during the workshop was slightly different from the design agenda due to last-minute changes in the availability of speakers and their topics.

Session III **Bottom-Up Technology Models**

14:00-14:45 The Brazilian Experience with Bottom-Up Models, Maurício Tiomno Tolmasquim and Emílio Lebre La Rovere, COPPE/UFRJ

14:45-15:30 Empirical Studies of Energy and Productivity Trends in Developing Countries, Alan Sanstad, Lawrence Berkeley National Laboratory (LBNL)

15:30-16:00 Comments and Discussion/Break

16:00-16:30 Modeling a Technology-Based Climate Strategy within an Equilibrium Framework, Alan Sanstad, LBNL

16:30-17:00 Discussion of Linking Bottom-Up and Top-Down Models, Luiz Fernando Loureiro Legey (COPPE/UFRJ), and Luiz Bevilacqua, National Laboratory of Computer Science (LNCC)

17:00-17:15 Wrap-Up

Tuesday, 20 March 2001

Session IV **Modeling Resource Endowments**

8:30-9:00 Forestry Issues, Eustáquio Reis, IPEA, and Elisabeth Sherrill, Planave S.A.

9:00-9:30 Forestry Mitigation Potential and Cost, Paul Schwengels, EPA

9:30-10:00 The Case of Hydroelectricity, Luiz Pinguelli Rosa, COPPE/UFRJ

10:00-10:30 Comments and Discussion

10:30-10:45 Break

Session V **Modeling Other Gases**

10:45-11:30 The Brazilian National Communication, Newton Paciornick, Ministry of Science and Technology (MCT)

11:30-12:15 Modeling Non-CO2 Gases, Alexei Sankovski, ICF Consulting

12:15-12:45 Comments and Discussion

12:45-14:00 Working Lunch

Session VI Some Modeling Applications

14:00-14:30 Impacts of Foreign Trade on Energy Use and CO2 Emissions of Brazil, and Energy Consumption and Carbon Emissions from Household Expenditures in Brazil, Roberto Schaeffer, COPPE/UFRJ

14:30-15:00 Co-control and Ancillary Benefits, Ronaldo Seroa da Motta, IPEA

15:00-15:30 Modeling the Health Benefits of Carbon Emissions Reductions: The Case of China, Richard Garbaccio, EPA

15:30-16:15 Comments and Discussion/Break

Session VII Future Cooperation

16:15-16:45 Open Discussion, Luiz Pinguelli Rosa and Roberto Schaeffer, COPPE/UFRJ

16:45-17:30 Summary and Finalizing Future Activities

17:30-17:45 Wrap Up and Conclusions

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Appendix B

List Of Participants

1. Luiz Pinguelli Rosa, PPE/COPPE/UFRJ
2. Roberto Schaeffer, PPE/COPPE/UFRJ
3. Luiz Gylvan Meira Filho, AEB
4. Michael Shelby, U.S. EPA
5. Carlos Feu Alvin, ABACC
6. Otávio Tourinho, IPEA
7. Emilio La Rovere, PPE/COPPE/UFRJ
8. Ronald Sands, PNNL
9. Mauricio Tolmasquim, PPE/COPPE/UFRJ
10. Alan Sanstad, LBNL
11. Luiz Fernando Legey, PPE/COPPE/UFRJ
12. Eustáquio Reis, IPEA
13. Elisabeth Sherrill, Planave S/A
14. Newton Paciornick, MCT
15. Alexei Sankovski, ICF Consulting
16. Ronaldo Seroa Da Motta, Ipea
17. Richard Garbaccio, U.S. EPA
18. Jeff Logan, PNNL
19. Ricardo Cunha, PPE/COPPE/UFRJ
20. Mauro Almeida, PPE/COPPE/UFRJ
21. Amaro Olimpio, PPE/COPPE/UFRJ
22. Giovani Machado, Anp (National Petroleum Agency)
23. Alexandre Szklo, PPE/COPPE/UFRJ
24. Marcio Costa, PPE/COPPE/UFRJ
25. Aluisio Machado, PPE/COPPE/UFRJ
26. Branca Americano, MCT
27. Ricardo Rodrigues, MCT
28. Marco Aurélio Santos, PPE/COPPE/UFRJ

29. Claude Cohen, PPE/COPPE/UFRJ
30. Alexandra Magrini, PPE/COPPE/UFRJ
31. Rafael Schechtman, ANP

Appendix C

Workshop Presentation Material

C-1: Paul Schwengels and Michael Shelby: U.S. Economic and Environmental Modeling Issues

C-2: Carlos Feu Alvim: Brazilian Experience with Top-Down Models

C-3: Octavio Tourinho: Top-Down CGE Models

C-4: Ron Sands: Update on the Brazilian Module of the Second Generation Model

C-5: Emilio Lebre La Rovere: Update on the Brazilian Module of the Second Generation Model

C-6: Alan Sanstad – Empirical Studies of Energy and Productivity Trends in Developing Countries (with Skip Laitner)

C-7: Alan Sanstad – Modeling a Technology-Based Climate Strategy within an Equilibrium Framework (with Skip Laitner)

C-8: Luiz Fernando Loureiro Legey: Linking Bottom-Up and Top-Down Models

C-9: Elisabeth Sherrill: Land Use Patterns, Deforestation in the Brazilian Amazon, and Global Effects, A Dynamic Model of Regional Ecological Economics

C-9A: Paul Schwengels: Forestry Mitigation Carbon Potential and Costs (with Jayant Sathaye)

C-10: Newton Paciornick: The Brazilian National Communication

C-11: Alexi Sankovski: Methane Marginal Abatement Curves for Major Emitting Countries

C-12: Roberto Schaeffer: Energy and Carbon Embodied in Brazilian International Trade

C-13: Ronaldo Seroa da Motta: Health and Economic Values for Mortality and Morbidity Cases Associated with Air Pollution in Brazil

C-14: Ronaldo Seroa da Motta: Economic Losses Due to Fire in the Amazon

C-15: Richard Garbaccio: Modeling the Health Effects of Carbon Emissions Reductions, The Case of China