Second Round Study Design for EMF 14: Integrated Assessment of Global Climate Change

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SECOND ROUND STUDY DESIGN FOR EMF 14: INTEGRATED ASSESSMENT OF CLIMATE CHANGE

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INTRODUCTION

This document describes the second round design of Energy Modeling Forum study number 14 entitled "Integrated Assessment of Climate Change." When the full working group meets again on May 24-26 of 1995 at Stanford University to review the results of the second round, this document will be revised based on the preferences of the working group at that time.

This document is composed of four main sections: (1) a description of the assumptions to be used by the modelers participating in the study in running the standardized reference scenario; (2) a set of scenario runs to be made around the standardized reference scenario and the modelers own reference scenario; (3) a description of the outputs requested from the modelers for all scenarios; and (4) a description of study groups being organized to interpret, expand upon and supplement the model runs. In past EMF studies the work of the study groups, although keyed to modeling work, has often addressed analytic issues that go beyond what is incorporated in all or most of the current generation of models.

REFERENCE CASE INPUT ASSUMPTIONS

As in all EMF studies, the standardization of input assumptions is accomplished so that important inputs take on common values for each EMF scenario. This process facilitates the interpretation of the model comparison, allowing one to separate the dependence of key model results on model structure and on specific numerical inputs. However, in instances where a particular model includes an endogenous computation of an input selected for standardization, the modeler is urged to use the internal calculation in lieu of the EMF 14 input assumption. By design this situation arises infrequently, but it is important for the modelers to maintain this flexibility. This avoids producing only "least common denominator" level results from the model comparisons. The standardization described in this preliminary study design pertains primarily to assumptions made to compute the costs of abating climate change, not those used to compute the benefits of avoiding climate impacts. Standardization of some of the key elements included in the calculation of benefits should occur in subsequent model comparison rounds as results of the initial rounds are reviewed and the state of the art in impacts modeling matures. Before discussing specific input values, the time periods and regional breakdown to be used in reporting model results are described. These dimensions of the study design condition the specification of the model inputs.

Time Periods

The global climate change problem is long run in nature. The time horizon for reporting model results needs to be much longer than that typically employed for other energy and environmental policy issues. Thus, the time horizon adopted for this study extends out to the year 2200. On the other hand, the most difficult and costly transitions (especially with discounting of future cash flows) will come in the next 10-50 years. Thus, the time periods adopted for reporting results for this study are shorter (every ten years) during the first 110 years of the study's time horizon than for the 22nd century (every 25 years). Consequently, the reporting years for the study are 1990, 2000, 2010, 2020, 2030, 2040, 2050, 2060, 2070, 2080, 2090, 2100, 2125, 2150, 2175, and 2200. Not every model will report all these years, nor will they report values for every output specified below. In addition at its second meeting the working group decided to show comparative results through 2100 only, and to use the results for 2125-2200 solely for help in interpreting model differences through 2100.

Geographical Regions

The main reporting regions for the study take into consideration the present and likely future geographical distribution of greenhouse gas emissions. The main reporting region totals are: (0) World Total, (1) U.S., (2) EEC, (3) OECD total (including the US and the EEC), (4) Former Soviet Union (FSU), (5) China, and (6) Non-OECD total (including the FSU and China). For those who produce estimates for other regions or individual countries, results for these subregions may also be reported.

Population and Economic Growth

The reference case includes assumptions about both population and economic growth. The assumptions chosen here are patterned after those made in the Intergovernmental Panel on Climate Change's (IPCC's) IS92A scenario (IPCC, 1992; Pepper, et al., 1994). As in that scenario, we extrapolate population growth projections contained in a World Bank (1991) report. These population assumptions are shown in Table 1.

The economic growth rates for the nineties for all regions represent reasonable extrapolations of actual economic performance from 1990 to 1994. With the exception of China and the Former Soviet Union, the economic growth rate assumptions adopted here from 2000 through 2100 are also drawn from the IPCC's IS92A scenario. The recent collapse of the economies of the Former Soviet Union make projecting future growth there extremely difficult. The projections shown in Table 2 show a decline in economic output in the FSU from 1990 to 2000, followed by a steady recovery over the first quarter of the next century. As shown in Table 2, the GDP growth rates assumed here decline gradually after 2000 (after 2025 in the case of the Former Soviet Union) due to structural change and lower population growth.

Also shown in Table 2 are estimates of GDP for 1990 for the study regions. Except for the FSU and China, these estimates are consistent with a number of published estimates. For the FSU and China, there exists considerable uncertainty regarding the purchasing power parity adjustments necessary to translate economic activity measured in non-convertible currencies into dollars. This conversion is complicated for these two major countries because of the absence of market-based pricing systems. Our approach here for both China and the FSU was to take the average of the official market exchange rate GDP estimates and purchasing power parity estimates. These two sets of estimates appear to span the range of current thinking in this area. Our averaging procedure does, however, result in much higher GDP estimates for China and than FSU than those computed at market exchange rates (about a factor of three higher for China and a factor of two higher for the FSU). The GDP per capita projections are plotted in Figure 1, which shows that the non-OECD countries achieve a much higher percentage of average OECD per capita GDP by 2200 than today, but that large differences remain. For example, the U.S. GDP per capita is a factor of almost 19 larger than that in China in 1990, but only a factor of two larger in 2200.

Table 1

Population Assumptions

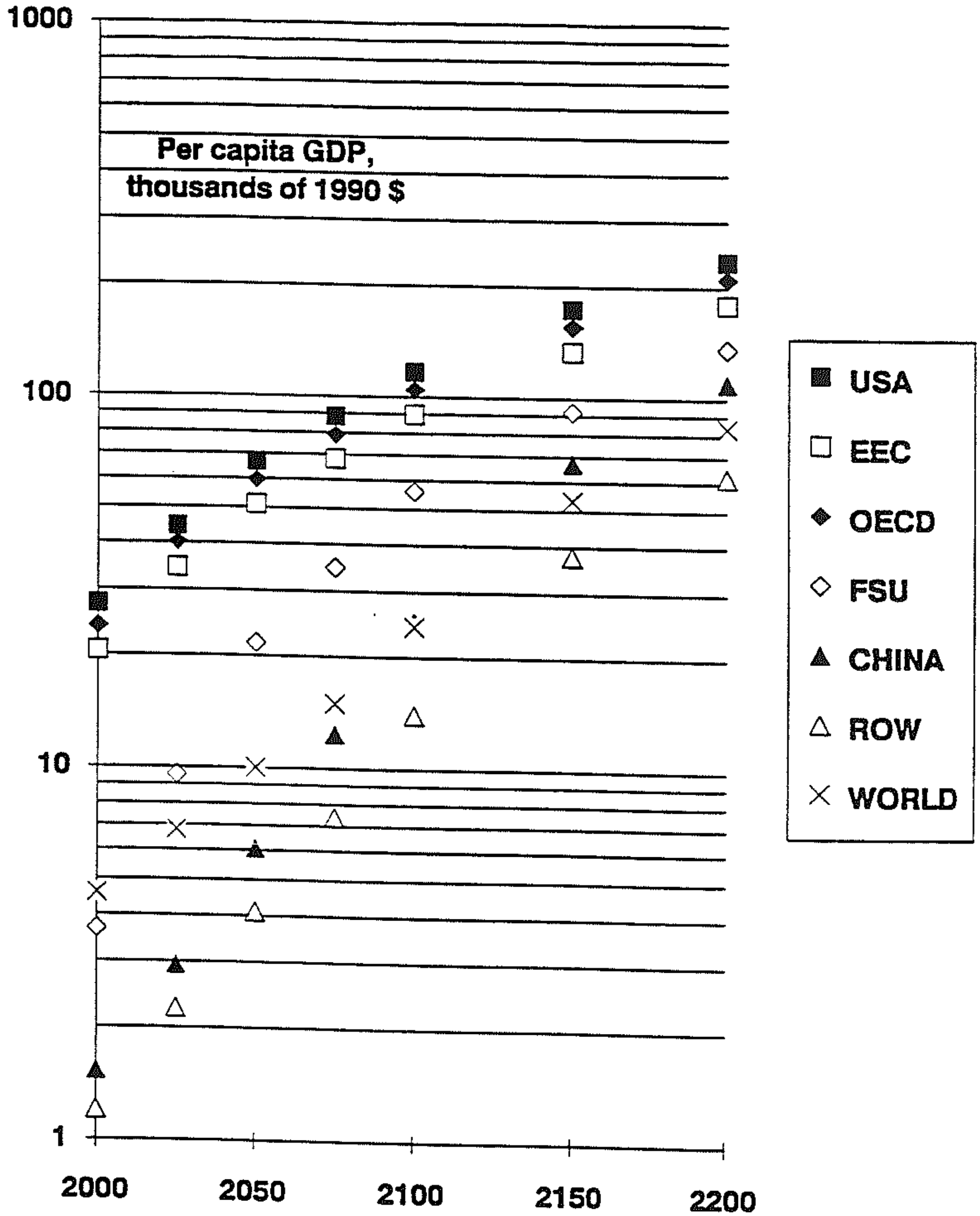
Region	1990 Level (10^6)	Projections (Millions)				
		2000	2025	2050	2075	2100-2200
USA	250	258	280	272	269	268
EEC	344	356	375	366	362	361
Other OECD	259	271	284	278	276	274
FSU	289	306	337	351	361	367
China	1134	1285	1576	1703	1750	1817
Other Non-OECD	2976	3729	5562	7061	7831	8225
World Total	5252	6205	8414	10031	10,849	11,312

Table 2

Economic Growth Rate Assumptions

Region	1990 GDP Trillions (per capita)	GDP Growth Rates (per capita growth rates)						
		1990-2000	2000-2025	2025-2050	2050- 2075	2075-2100	2100-2150	2150-2200
USA	5.52 (22,080)	2.50% (2.18)	2.30% (1.97)	1.50% (1.62)	1.10 (1.14)	1.10% (1.12)	.80% (.80)	.60% (.60)
EEC	5.71 (16,599)	2.50% (2.15)	2.30% (2.09)	1.50% (1.60)	1.10% (1.14)	1.10% (1.11)	.80% (.80)	.60% (.60)
Other OECD	4.97 (19,189)	2.70% (2.24)	2.30% (2.11)	1.50% (1.59)	1.10% (1.13)	1.10% (1.13)	.80% (.80)	.60% (.60)
FSU	1.31 (4533)	-1.50% (-2.0)	4.30% (3.90)	3.50% (3.33)	2.00% (1.89)	2.00% (1.93)	1.00% (1.00)	.80% (.80)
China	1.33 (1173)	4.00% (2.71)	3.50% (2.66)	3.25% (2.93)	3.00% (2.89)	3.00% (2.85)	2.00% (2.00)	1.00% (1.00)
Other non-OECD	3.11 (1045)	3.75% (1.44)	4.20% (2.55)	3.40% (2.42)	2.80% (2.38)	2.80% (2.60)	2.00% (2.00)	1.00% (1.00)
World Total	21.95 (4179)	2.63% (.93)	2.84% (1.59)	2.27% (1.55)	1.94% (1.62)	2.11% (1.94)	1.60% (1.60)	.90% (.90)

Figure 1. EMF 14 Per Capita GDP Assumptions



Oil Prices and Fossil Fuel Resource Base

For modelers requiring exogenous oil price inputs the world price of oil should be assumed to be $20/barrel through the year 2000 in 1990 dollars and then to increase $6.00 per barrel each decade until 2050 (reaching the backstop level of $50/barrel in that year). For modelers requiring oil and gas resource base estimates, the 95th percentile estimates from Masters, Attanasi, and Root (1994), summarized here in Table 3 are recommended. Recommended estimates for ultimately recoverable coal resources are also shown in Table 3. These oil, gas, and coal sector assumptions should be employed in all first round scenarios.

Technology Costs

New coal-fired power plants are assumed to be able to generate electricity for 50 mills/kWh, with an overall efficiency of 34%, and a carbon emission coefficient of .25 metric tons carbon per thousand kilo-watt hours. It is assumed that four advanced "backstop" technologies will become available:

(1) A liquid synthetic fuel derived from coal or shale at $50/barrel of crude oil equivalent, and a carbon emission coefficient of .04 metric tons carbon per billion joules (or 40 million tons per exajoule) available for the first time in 2010.

(2) A non-carbon based liquid fuel at $80/barrel of crude oil equivalent, available for the first time in 2010.

(3) A non-carbon based electric option at 75 mills/kWh first available in 2010.

(4) A non-carbon based electric option at 50 mills/kWh first available in 2030.

Table 3

Resource Base Assumptions
(Exajoules of Economically Recoverable Resources)

Resource	Category	USA	EEC	Other OECD	FSU	China	Other Non-OECD	World
Crude Oil + Nat. Gas Liquids	Reserves	398	166	229	916	230	5423	7362
	Undiscovered resources, 95th* percentile	455	166	511	1709	534	3458	6833
	TOTAL	853	332	740	2625	764	8881	14,195
Natural Gas	Reserves	365	198	343	1673	42	2916	5537
	Undiscovered resources, 95th* percentile	415	144	1099	4703	460	3984	10,805
	TOTAL	780	342	1442	6376	502	6900	16,342
Coal	Ultimately Recoverable Resources	45,000	5,000	10,000	60,000	60,000	120,000	300,000

Source: Masters, Charles D., Emil D. Attanasi, and David H. Root, "World Petroleum Assessment and Analysis," Proceedings of the 14th World Petroleum Congress Stavanger, Norway, John Wiley and Sons, Ltd. 1994.

* These values are referred to as 5th percentile values in Master's, et. al.. Here we use standard probability theory cumulative distribution convention. Thus, there is a 95% probability that the actual amount of undiscovered resources will turn out to be less than the values shown in the table.

Energy Efficiency Improvements

In many of the models a key determinant of future energy demand is the rate at which energy use per unit of economic activity is projected to trend down independently of any future energy price changes. This trend, which includes the effects of both technological progress and shifts in economic structure, is often represented with a single aggregate parameter referred to as the Autonomous Energy Efficiency Improvement (AEEI) rate. Recent expert opinion polls report an AEEI of about .7 percent per year for the U.S. (e.g., Manne and Richels, 1994) in the near term. The regional and longer term U.S. AEEI values shown in Table 4 result from a simple formula suggested by Arnulf Grubler of IIASA. The formula assumes that AEEI improvements are a constant fraction of the projected GDP per capita growth rates. Dividing the short-run AEEI projection for the U.S. by the U.S. GDP per capita projection for 1990-2000 of 2.18% yields .32; the per capita GDP projections for each time period in each period are multiplied by this factor to get the AEEI values shown in Table 4. This approach insures some degree of consistency among the AEEI assumptions made across time periods and regions. These AEEI projections should be used by models that use this approach to energy demand modeling. In addition to these AEEI assumptions, there may be additional energy efficiency improvements that are independent of world energy price changes in models where energy subsidies in certain countries (which have been substantial in the FSU and many developing countries) are reduced from their 1990 levels.

Discount Rates

If your model does not calculate a discount rate internally, assume that the near-term marginal product of capital is 5 percent.

Table 4
Autonomous Energy Efficiency Improvement Rate Assumptions

Region	AEEI Rates (percent per year rates)						
	1990-2000	2000-2025	2025-2050	2050-2075	2075-2100	2100-2150	2150-2200
USA	.70%	.63%	.52%	.37%	.36%	.26%	.19%
EEC	.70%	.67%	.51%	.37%	.36%	.26%	.19%
Other OECD	.72%	.67%	.51%	.36%	.36%	.26%	.19%
FSU	-.66%	1.25%	1.07%	.60%	.62%	.32%	.26%
China	.87%	.85%	.94%	.92%	.91%	.64%	.32%
Other Non-OECD	.46%	.81%	.77%	.76%	.83%	.64%	.32%

This concept is often used as the discount rate for discounting goods and services. If you use some other method for computing a discount rate internally, please provide a description with your results.

SCENARIOS

The first round EMF 14 scenarios are generic policy excursions rather than detailed model structure investigations or policy implementation excursions. Two separate reference cases are to be considered:

(0) a modelers reference case with no changes in existing policies assumed and each modeling team using its preferred set of population, economic growth, natural resource and technology assumptions,

(1) a standardized reference case with no climate change impacts and no changes in existing policies assumed and the reference case assumptions described above used at inputs to each model.

In addition to these two reference scenarios the following scenarios are included in round #2 of EMF 14 (note that scenarios 0,1,2,3,5,6, and 7 are the same as first round scenarios, and that scenario #4 limits the global mean temperature increase rather than round #1's limit on climate damages):

(2) (1) + Limit Carbon Emissions to No More Than 1990 Levels.

(3) (1) + Limit CO_2 Concentrations to No More Than 550 ppmv.

(4) (1) + Limit Temperature Increase to No More Than 2°C wrt 1990

(5) (1) + Pareto Optimal Emissions
(Balance Costs and Benefits of CO_2 Control)

(6) (1) + Accelerated Technology

(7) (1) + Modelers Choice Policies
(Each Modeler Picks Favorite Scenario)

Scenarios (8)-(12) are identical to (2)-(6), but are to be run using the Modelers Reference Case assumptions rather than the Standardized Reference Case Assumptions.

(8) (0) + Limit Carbon Emissions to No More Than 1990 Levels.

(9) (0) + Limit CO_2 Concentrations to No More Than 550 ppmv.

(10) (0) + Limit Temperature Increase to No More Than 2°C wrt 1990

(11) (0) + Pareto Optimal Emissions
(Balance Costs and Benefits of CO_2 Control)

(12) (0) + Accelerated Technology

In the accelerated technology scenario it is assumed that:

(i) 400 Exajoules of low-cost biomass resources are first available in 2020.

(ii) 20% of this resource is available at $1.40 per exajoule, and the remaining 80% at $2.40 per exajoule.

(iii) A prohibition on the re-introduction of a technology once it has been abandoned.

Limits on the atmospheric concentration of CO_2 scenarios have been studied extensively by Working Group I (the science assessment working group) of the IPCC. The accelerated technology scenario (scenario 6) was developed by the energy supply mitigation options team of IPCC Working Group II, based on work on biomass energy by Williams (1994).

The policies to be used to achieve the emission reductions are left up to the discretion of the modeling teams. It was argued that this type of scenario design would be most useful to policy makers and would reveal a great deal about the policies under consideration, the representation of these policies in the models, and model behavior. We will, however, ask each modeling team to specify the policies they have employed to achieve the specified emission reductions. If your model does not consider trading in carbon emission rights between regions, vary emissions in each region as you see fit to meet the various scenario targets.

Diagnostic Scenarios. The next three scenarios (13, 14, and 15) involve fixing the carbon emission (13), CO_2 concentration (14), and global mean temperature (15) trajectories input to the models, respectively (this type of scenario was originally proposed by Rob Mendelsohn prior to the IIASA meeting). This should enable us to isolate differences in the carbon cycle, climate, and damage components of the models, and to compare results with more elaborate component models developed by discipline specialists:

(13) Input Carbon Emissions From IPCC Scenario IS92A shown in the first column of Table 5.

(14) Input Carbon Dioxide Concentrations Projected by the MAGICC Model With the IS92A emissions as input shown in the second column of Table 5.

(15) Input Global Mean Temperatures Projected by the MAGICC Model With the IS92A emissions as input shown in the third column of Table 5.

The emissions trajectory in (13) is an extrapolated version of the emissions trajectory contained in Pepper, et al. (1992, p. 101) for the IS92A scenario, while the concentration and temperature trajectories are those produced by the MAGICC model (Wigley, 1994) for the IS92A scenario with the "default" set of gas cycle, climate and sea level parameter assumptions. Available information on other greenhouse gas emissions are shown in Appendix Table A-2, for other gas concentrations in Appendix Table A-3, and for other climate variables in Appendix Table A-4, for those who need it.

Table 5

Inputs for Diagnostic Scenarios

	Scenario #13	Scenario #14	Scenario #15
Year	Carbon Emissions (BMt Carbon)	CO_2 Conc. (ppmv)	Temp.Change (°C)
1990	6	355	0
2000	7	374	0.16
2010	8.3	396	0.32
2020	9.8	422	0.48
2030	11.2	452	0.66
2040	12.1	482	0.85
2050	13.2	515	1.05
2060	14.3	549	1.28
2070	15.5	584	1.52
2080	16.8	622	1.77
2090	18.2	665	2.01
2100	19.8	714	2.27
2125	23.8	837	2.92
2150	27.8	959	3.57
2175	31.8	1082	4.22
2200	35.8	1204	4.87

Impact Scenarios. Policy makers are ultimately interested in much more complex scenarios than those described above. Much of what is of interest to them goes beyond what the current integrated assessment models can examine, but this situation is improving rapidly. Joel Scheraga and Susan Herrod of EPA have formulated a set of five generic "impact" scenarios, to demonstrate some of the things that may be of most interest to domestic policy makers and international negotiators. Modelers should run as many of these scenarios as they can and assess what it would take to be able to the remaining ones in the future. The impact scenarios should ideally be considered with respect to the impacts on economic sectors and ecosystem types over time resulting from a range of climate scenarios:

Scenario (16): Examination of mitigation and/or adaptation strategies that help insure that various ecosystems maintain the ability to adapt naturally to alternative rates of climate change, while not exceeding acceptable rates (or levels) of net economic loss.

Policy Issue: Should a metric for determining policy be sensitive to the rate at which ecosystems and/or economic systems are able to adapt to climate change? This is relevant for meeting the objectives of Article 2 of the Framework Convention on Climate Change.

Scenario (17): Examination of the effect of potential discontinuities or irreversibilities in physical, biological or economic systems on the choice of policies.

Policy Issue: How important might the existence of discontinuities or irreversibilities be for climate policy? How important is it to consider the probabilities of different outcomes occurring?

Scenario (18): Compare preferred policies for achieving some "equity" in the distribution of impacts across different countries/regions to preferred policies for minimizing total global impacts.

Policy Issue: The development of international protocols--and the acceptability of those protocols to different countries--will require an examination of the distributional impacts of climate change across different countries.

Scenario (19): Examination of mitigation and/or adaptation strategies that would ensure that an acceptable level of loss of agricultural production is not exceeded.

Policy Issue: Article 2 of the Framework Convention on Climate Change also requires that dangerous anthropogenic interference in the climate system be avoided in order to ensure that food production is not threatened Hence it is useful to have a scenario which examines global agricultural production in particular.

Scenario (20): Effect of increases in the frequency and severity, and changes in the distribution of, extreme weather events (including drought, storms, and floods) on ecosystem types and economic sectors under alternative climate scenarios and policy options.

Policy Issue: A key uncertainty is the potential effect of climate change on the frequency of extreme events. As countries consider making investments to "insure" against uncertain future climate impacts, inclusion of extreme events is warranted.

Since it is unlikely that many of the models can presently run many of these scenarios, it is pleasing to note that the "Analysis for Decisions Under Uncertainty" study group (see below) is exploring issues related to scenario #17, and the "Distribution of Costs and Benefits" study group is starting to investigate the issues included in scenario #18.

The Second Round EMF 14 scenarios are displayed in Figure 2 (developed by James Sweeney), which shows two dimensions to the model comparisons--a vertical "policy" dimension and a horizontal "model diagnostic" dimension. The additional lines shown for scenarios 2, 3, and 4 illustrate that these generic policy option scenarios also provide some diagnostic information as carbon emissions, carbon dioxide concentrations, and temperatures, respectively, are limited in these scenarios. Thus, to the extent that the limits are binding (usually the case) these scenarios provide another source of diagnostic information regarding the carbon cycle, climate, and impacts modules of the models, albeit one far from the reference case operating points of these modules.

Figure 2
EMF 14 Scenario Map
(a.k.a. Sweeney Diagram)

Generic Policy	Level at Which Standardization is Imposed				
	Modelers Reference	EMF Reference (Standardize Econ. & Technology Drivers)	Standardize CO_2 Emissions	Standardize CO_2 Concentrations	Standardize Global Temperatures
No Intervention	**0**	**1**	**13**	**14**	**15**
Limit Carbon Emissions (1990 Level)	**8**	**2**	**2**	**2**	
Limit CO_2 Concentrations (550 ppmv)	**9**	**3**		**3**	**3**
Limit Global Temperatures (+2°C wrt 1990)	**10**	**4**			**4**
Pareto Optimal CO_2 Emissions	**11**	**5**			
Accelerated Technology	**12**	**6**			
Other Policy Scenarios	**16-20**	**7**			

OUTPUTS REQUESTED

Table 6 shows the output variables being requested from each model for each reporting year and region for each scenario. For the energy variables, the format is patterned after that used in the BP Statistical Review of World Energy, (British Petroleum, p.l.c, June 1992), primary energy includes commercially traded fuels only. Excluded therefore are fuels such as wood, peat and animal waste which, though important in many countries, are unreliably documented in terms of consumption statistics. Alan Manne graciously provided the 12-region summary of this data which is included as Appendix Table A-1 to this document. If your model is more disaggregated than reflected in Table 6, consult that table.

Also shown in Table 6 are our best estimates for values for the reporting variables for 1990. Actual reporting of data will be implemented in Lotus format via floppy disks to be provided by EMF headquarters. There will be alphanumeric labels for each data series, but blank data fields to be filled in by participating modelers.

Energy quantities should be expressed in terms of "net" calorific value. The difference between the "net" and the "gross" calorific value for each fuel is the latent heat in condensation of the water vapor produced during combustion of the fuel. For coal and oil, net calorific value is about 5 percent less than gross. For most forms of natural and manufactured gas, the difference is 9-10 per cent, while for electricity there is no difference. The use of net calorific value is consistent with the practice of the Statistical Offices of the European Communities and the United Nations.

Table 6 **Output Reporting Form**
(estimated 1990 values shown)

Variable	USA	EEC	OECD Total	FSU	China	Non-OECD Total	World Total
PRIMARY ENERGY CONSUMPTION (Exajoules)							
Coal/Shale	20.1	11.9	39.4	11.8	21.7	52.8	92.2
Total Fossil Fuels	73.2	43.6	148.2	52.9	26.9	149.6	297.8
Total Primary Energy	82.7	50.9	176.3	57.7	28.2	165.6	341.9
ELECTRIC GENERATION (Trillion KwH)	2.80	1.96	6.90	1.73	.62	4.75	11.65
ATMOSPHERE/CLIMATE							
Total Carbon Emissions[a] (million metric tons)	1417	863	2902	960	623	2962	5864
Total Sulfur Emissions (million metric tons)							
CO_2 Concentration (ppmv)							353
CH_4 Concentration (ppbv)							1720
ΔT (°C wrt 1990)							-
Sea Level Rise (cm wrt 1990)							-
ECONOMICS (Bil. 1990$s)							
Gross Domestic Product	5520	5710	16,200	1310	1330	5750	21950
Climate Change Costs							
Control Costs [b]							
Carbon Tax (1990$/metric ton carbon)							
LAND USE (million hectares)							
Agricultural Area							
Forest Area							
PHYSICAL IMPACTS							
Ecosystem Under Stress (million hectares)							
Area Lost to Sea Rise (mil.hectares wrt 1990)							
Mortality (deaths per 1000 people)							
Fresh Water Supply (Fraction of 1990)							

[a] Not corrected for non-energy uses of fossil fuel. Following Marland and Boden, Statement before the Senate Committee on Energy and Natural Resources, July 26, 1989, computed by assuming emissions' coefficients of 19.94 million metric tons of carbon per exajoule of primary oil consumption, 13.74 for natural gas and 24.12 for coal.

[b] Relative to the appropriate reference scenario (scenario 0 or 1).

Sources: Primary Energy - British Petroleum (1992).
Fuels for Electric Generation - International Energy Agency (1992).
Atmospheric Concentrations - IPCC (1992).

STUDY GROUPS

Five study groups have been established to investigate issues relevant to integrated assessment, but not necessarily considered (or handled well) in the existing set of models:

Preliminary EMF 14 Study Groups	**Chairman**
Analysis for Decisions Under Uncertainty	Alan Manne (Stanford)
Impacts of Climate Change	John Reilly (USDA)/ Sally Kane (CEA)
Distribution of Costs and Benefits	Jae Edmonds (PNL)/ Richard Richels (EPRI)
Long-Term Economic Growth Projections	William Nordhaus (Yale)
Discounting and Valuation Issues	Robert Lind (Cornell)

The Analysis for Decisions Under Uncertainty study group is employing some of the models participating in the base model comparison exercise--DICE, MERGE, ICAM-2, PAGE, and PEF--as well a number additional smaller-scale research models (the Kolstad, Hammitt, Lempert/Schlesinger, and Yohe/Schlesinger models) that focus explicitly on uncertainty and learning to explore the potential impact of uncertainties in key model inputs and structural assumptions on climate change policy decisions. The Impacts of Climate Change study group is assessing how climate impacts are represented in integrated assessment models and the extent to which recent research from the relevant disciplines could improve the state of the art. The Distribution of Costs and Benefits study group is beginning to explore what the models say about the international allocation of emissions rights and responsibilities for paying for emission reductions as a precursor to international negotiations on these issues. The Long-Term Economic Growth Projections study group is assessing expert opinions on long-term economic growth in various world regions over the next 200 years through a questionnaire designed by William Nordhaus at Yale University. Not much effort has gone into developing such assumptions although they are crucial in global change policy analyses. The Discounting and Valuation study group is exploring a number of valuation issues that are fundamental to assessments of the magnitude of the climate change problem and potential policy responses to it, including initially the discount rate and ultimately the valuation of non-market impacts. The Analysis of Decisions Under Uncertainty Group and the Impacts of Climate Change groups were organized at the first working group meeting in June 1994, and the three additional study groups were organized at the second meeting in December. Thus, somewhat more detailed reports are now presented for the two groups that were formed at the first meeting.

Analysis for Decisions Under Uncertainty Study Group

This group currently consists of modelers who can incorporate uncertainty in their modeling systems, although the modelers are anxious to recruit knowledgeable non-modelers into the group as the study proceeds. Alan Manne is chairing this group, and a preliminary list of mutually agreed upon uncertainty scenarios have been developed. The "Uncertainty" group was renamed the "Analysis for Decisions under Uncertainty" group at their January 19-20 meeting at Stanford. This group will focus on low probability scenarios with highly unfavorable consequences. These are to be contrasted with the high probability, low consequence EMF standardized scenarios. By "low probability", we mean e.g. the 10% or 5% or 1% tails of the distributions. Modelers are encouraged to conduct parametric analysis to determine how high must be the probability of these scenarios to affect near-term decisions. What combination of assumptions is needed in order to make global emissions stabilization a logically defensible policy?

Some models can accommodate only a small number of scenarios, but others can handle a much larger number. The latter should be encouraged to provide insights into what is learned by moving from, say, a two-point discrete distribution toward five scenarios, 500, or 500,000.

The discount rate is crucial in the greenhouse debate. The group suggests contrasting two different approaches: a descriptive view (oriented toward market behavior) based on a 5% real net rate of return on capital, and a prescriptive view (based on intergenerational equity considerations) which could lead to a rate as low as 2%. For those models in which aggregate savings and investment are driven by intertemporal utility maximization, the 2% view is likely to lead to a rapid immediate step up in the rate of investment.

Hedging strategies are to be constructed under two or three alternative values of the climate sensitivity parameter: a 2.5, 5 or 10 degrees mean temperature increase associated with a doubling of CO_2 concentrations. Alternative dates for resolution of this uncertainty: 1995 or just after 2020 or just after 2050.

For those models employing aggregate damage functions, a 2% GDP loss associated with a 2.5 degree mean global temperature increase (from 1990) is recommended with a quadratic extrapolation from that point. For a low probability scenario, modelers are encouraged to employ more steeply rising damage functions. Two examples of such a function would be a cubic or a "hockey-stick" form. Comparative results from these scenarios should be available by the May 24-26, 1995 meeting of the working group.

Impacts of Climate Change Study Group

The objective of this group is to bring together key researchers on natural systems impacts of climate change with integrated assessment modelers, climate modelers, and valuation of impacts researchers. This group will identify required inputs and desired outputs from each group, including uncertainty measures as appropriate. It will start by defining the state of the art in each community and work towards improved communication and integration. Because of the difficulty of scheduling the key impacts researchers and the full working group simultaneously, this study group will meet on its own independently of the working group meetings and provide information and analysis to the full EMF 14 working group. At present efforts are centered on putting together a workshop on representing the impacts of climate change in integrated assessment models during the summer of 1995 (with a follow on meeting in the fall). In addition, key participants in the study group meetings will be asked to join the EMF 14 working group if interested. John Reilly of the U.S. Department of Agriculture and Sally Kane of the Council of Economic Advisers are coordinating the work of this study group.

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June 13, 1994

Professor John Weyant
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Dear John:

In your guidelines to EMF 14 modelers, you are welcome to include the attached spreadsheet. It is based on the BP Statistical Review of World Energy, June 1992. The spreadsheet was constructed in early 1993 as part of the statistical base for my 12RT model. The same 12 regions are distinguished as in the OECD's GREEN model. The following special-purpose abbreviations are employed:

OOECD	OECD other than USA, Japan and EEC
ENX	energy exporting countries
FUSSR	former USSR
CEEUR	central and eastern Europe
DAE	dynamic Asian economies
ROW	rest of world

The spreadsheet provides a globally consistent summary for 1990. For each of the 12 regions, it indicates primary energy consumption, carbon emissions, oil and gas production and net imports of oil and gas.

One caveat: BP reports nuclear energy "on the basis of the average thermal efficiency of a modern nuclear power plant (i.e. 33% efficiency)", but it reports hydroelectricity "on the basis of the energy content of the electricity generated". That is, hydroelectricity consumption is based on 100% conversion efficiency rather than on fossil fuel replacement value. These accounting conventions do not affect the estimation of carbon emissions in 1990, but they do affect the measurement of total primary energy consumption in countries such as Brazil, where hydroelectricity is a major element in the fuel mix.

Best regards,

Alan S. Manne

Table A - 1

ENDAT.XLS

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	1990 total primary energy consumption - mtoe; source: BP , 6/92, p. 34.														
2															
3		USA	JAPAN	EEC	OOECD	ENX	CHINA	FUSSR	INDIA	CEEUR	DAE	BRAZIL	ROW	WORLD	mtC/exaj
4	Oil	781.5	242.9	539.7	196.3	361.0	110.3	425.3	57.9	87.3	124.9	63.3	151.0	3141.4	19.9
5	Gas	486.3	45.4	217.1	88.5	204.2	13.2	557.4	11.2	62.5	12.2	3.6	68.1	1769.7	13.7
6	Coal	480.9	76.0	285.4	97.6	53.1	518.9	280.7	102.4	160.9	41.9	9.3	93.8	2200.9	24.1
7	Nuclear	155.9	50.7	141.0	46.1	.0	.0	55.2	1.6	15.1	19.5	.6	5.2	490.9	
8	Hydro	24.7	7.7	11.4	50.9	13.7	10.9	20.0	5.5	4.9	2.0	17.5	22.1	191.3	
9	Total	1929.3	422.7	1194.6	479.4	632.0	653.3	1338.6	178.6	330.7	200.5	94.3	340.2	7794.2	
10															
11	Estimated carbon emissions from fossil fuels, million tons C:														
12		1418	306	864	313	472	624	959	158	271	154	64	260	5864	
13															
14	1990 oil and gas production - mtoe; source: BP, 6/92,pp.4, 20.														
15		USA	JAPAN	EEC	OOECD	ENX	CHINA	FUSSR	INDIA	CEEUR	DAE	BRAZIL	ROW	WORLD	
16	Oil	420.6	.0	119.8	203.6	1577.6	138.3	570.8	33.9	18.0	.0	33.0	16.9	3132.5	
17	Gas	454.2	1.8	137.7	137.3	276.6	13.2	655.4	13.0	30.8	1.8	.0	56.6	1778.4	
18															
19	1990 oil and gas implied imports - exports (mtoe).														
20	Oil	360.9	242.9	419.9	-7.3	-1216.6	-28.0	-145.5	24.0	69.3	124.9	30.3	134.1	8.9	
21	Gas	32.1	43.6	79.4	-48.8	-72.4	.0	-98.0	-1.8	31.7	10.4	3.6	11.5	-8.7	
22															
23	1990 production - exajoules				41.87	PJ per mtoe		123.1	PJ per mtoe @34% efficiency for hydro						
24		USA	JAPAN	EEC	OOECD	ENX	CHINA	FUSSR	INDIA	CEEUR	DAE	BRAZIL	ROW	WORLD	
25	Oil	17.6	.0	5.0	8.5	66.1	5.8	23.9	1.4	.8	.0	1.4	.7	131.2	
26	Gas	19.0	.1	5.8	5.7	11.6	.6	27.4	.5	1.3	.1	.0	2.4	74.5	
27	Coal	20.1	3.2	11.9	4.1	2.2	21.7	11.8	4.3	6.7	1.8	.4	3.9	92.2	
28	Nuclear	6.5	2.1	5.9	1.9	.0	.0	2.3	.1	.6	.8	.0	.2	20.6	
29	Hydro	3.0	.9	1.4	6.3	1.7	1.3	2.5	.7	.6	.2	2.2	2.7	23.6	
30	Total	66.3	6.3	30.0	26.6	81.5	29.4	67.9	7.0	10.0	2.9	4.0	9.9	341.9	
31															
32	1990 oil and gas implied imports - exports (exajoules)														
33		USA	JAPAN	EEC	OOECD	ENX	CHINA	FUSSR	INDIA	CEEUR	DAE	BRAZIL	ROW	WORLD	
34	Oil	15.1	10.2	17.6	-.3	-50.9	-1.2	-6.1	1.0	2.9	5.2	1.3	5.6	.4	
35	Gas	1.3	1.8	3.3	-2.0	-3.0	.0	-4.1	-.1	1.3	.4	.2	.5	-.4	
36															
37	COAL-R	16.4	2.8	5.1	1.7	3.9	5.9	5.0	1.4	1.4	1.2	.1	2.1		
38	CLDU	3.5	.4	6.8	2.3	-1.6	15.6	6.6	2.9	5.3	.6	.3	1.8		

Table A - 2

Global Emissions of Direct Greenhouse Gases
(IS92a)

	1990	2000	2025	2050	2100
CO_2 Emissions (Bt C)					
Energy	6.0	7.0	10.7	13.2	19.8
Deforestation	1.3	1.3	1.1	0.8	-0.1
Cement	0.2	0.2	0.4	0.5	0.6
Total	7.4	8.4	12.2	14.5	20.3
CH_4 Emissions (Tg)					
Energy Production and Use	91	94	110	140	222
Enteric Fermentation	84	99	138	173	198
Rice	60	66	78	87	84
Animal Wastes	26	31	43	54	62
Landfills	38	42	63	93	109
Biomass Burning	28	29	32	34	33
Domestic Sewage	25	29	40	47	53
Natural	155	155	155	155	155
Total	506	545	659	785	917
N_2O Emissions (Tg N)					
Energy	0.4	0.5	0.7	0.8	0.8
Fertilized Soils	2.2	2.7	3.8	4.2	4.5
Land Clearing	0.8	0.8	1.0	1.1	1.0
Adipic Acid	0.5	0.6	0.9	1.1	1.2
Nitric Acid	0.2	0.3	0.4	0.5	0.5
Biomass Burning	0.5	0.6	0.7	0.7	0.7
Natural	8.3	8.3	8.3	8.3	8.3
Total	12.9	13.8	15.8	16.6	17.0
Halocarbons (kilotons)					
CFC-11	299	168	94	85	2
CFC-12	363	200	98	110	1
CFC-113	147	29	21	24	0
CFC-114	13	4	3	3	0
CFC-115	7	5	1	1	0
CCl_4	119	34	19	21	0
Methyl Chloroform	738	353	97	110	0
HCFC-22	138	275	530	523	614
HCFC-123	0	44	159	214	267
HCFC-141b	0	24	82	110	138
HCFC-124	0	7	11	15	16
HCFC-142b	0	7	11	0	0
HCFC-225	5	17	30	38	40
HFC-134a	0	148	467	918	1055

Table A - 3

Climate model output: End of Year Gas Concentrations
(Reference scenario - user models)

Year	CO2 (ppmv)	CH4 (ppbv)	N2O (ppbv)	CFC-11 (pptv)	CFC-12 (pptv)	HCFC-22 (pptv)	Equiv. HFC134a (pptv)	Year
1990	355.0	1722.3	308.4	285.6	494.1	118.1	56.8	1990
1995	364.0	1808.9	309.2	315.0	548.0	133.0	100.0	1995
2000	373.7	1911.1	310.4	327.0	578.9	162.9	151.4	2000
2005	384.4	2011.3	312.0	326.0	592.7	200.5	208.6	2005
2010	396.1	2109.1	313.9	319.0	595.6	241.3	270.1	2010
2015	408.6	2204.8	316.1	310.9	592.1	285.6	332.5	2015
2020	422.2	2297.8	318.6	301.8	586.8	333.3	394.3	2020
2025	436.6	2396.1	321.6	292.3	581.6	384.7	455.6	2025
2030	451.6	2502.2	324.6	283.2	577.1	444.9	520.5	2030
2035	466.8	2613.5	327.7	274.6	573.5	514.3	590.6	2035
2040	482.3	2728.7	330.9	266.5	570.6	590.0	664.6	2040
2045	498.2	2846.8	334.0	258.8	568.4	670.2	741.6	2045
2050	514.6	2967.2	337.2	251.5	566.8	753.3	820.7	2050
2055	531.3	3076.8	340.4	243.0	563.1	826.7	892.0	2055
2060	548.5	3171.6	343.4	232.6	555.4	886.6	951.8	2060
2065	566.0	3256.6	346.4	220.4	543.9	937.2	1002.7	2065
2070	583.9	3334.9	349.2	206.5	528.8	981.4	1047.1	2070
2075	602.3	3408.6	351.9	191.2	510.4	1021.2	1086.5	2075
2080	621.8	3482.5	354.6	175.9	490.5	1052.2	1118.8	2080
2085	642.8	3558.2	357.3	161.4	470.7	1073.5	1143.6	2085
2090	665.1	3635.3	359.8	147.8	450.7	1088.3	1162.8	2090
2095	689.0	3713.6	362.4	135.0	430.8	1098.5	1177.8	2095
2100	714.2	3792.7	364.9	122.7	410.8	1105.7	1189.6	2100

Table A - 4

Climate model output: Temperature & Sea Level Rise Contributions
(Reference scenario - user models)

Year	dQ sum (W/m^2)	dTequ (degC)	dT (degC)	------------ sea level (cm) ----------- dmsl	thermal expn	small glacs	Greenl.	Antarc.	Year
1990	0.000	0.000	0.000	0.00	0.00	0.00	0.00	0.00	1990
1995	0.214	0.123	0.076	1.05	0.54	0.46	0.09	-0.04	1995
2000	0.426	0.244	0.159	2.28	1.16	1.01	0.20	-0.09	2000
2005	0.599	0.343	0.238	3.64	1.83	1.63	0.33	-0.15	2005
2010	0.782	0.447	0.317	5.08	2.53	2.29	0.48	-0.21	2010
2015	0.971	0.556	0.399	6.61	3.28	2.98	0.64	-0.28	2015
2020	1.144	0.655	0.480	8.21	4.07	3.68	0.82	-0.37	2020
2025	1.335	0.764	0.563	9.86	4.89	4.40	1.02	-0.46	2025
2030	1.550	0.887	0.655	11.58	5.77	5.12	1.25	-0.55	2030
2035	1.766	1.011	0.751	13.39	6.70	5.86	1.49	-0.66	2035
2040	1.981	1.134	0.849	15.27	7.68	6.62	1.75	-0.78	2040
2045	2.196	1.257	0.948	17.21	8.70	7.38	2.04	-0.90	2045
2050	2.415	1.382	1.050	19.20	9.76	8.13	2.34	-1.04	2050
2055	2.683	1.536	1.164	21.26	10.88	8.89	2.68	-1.19	2055
2060	2.942	1.684	1.284	23.43	12.07	9.67	3.04	-1.35	2060
2065	3.193	1.828	1.404	25.66	13.30	10.45	3.42	-1.52	2065
2070	3.437	1.968	1.524	27.93	14.57	11.23	3.84	-1.70	2070
2075	3.677	2.105	1.644	30.24	15.87	11.99	4.28	-1.90	2075
2080	3.925	2.247	1.765	32.58	17.21	12.74	4.74	-2.11	2080
2085	4.179	2.392	1.888	34.96	18.58	13.46	5.24	-2.33	2085
2090	4.437	2.540	2.013	37.37	20.00	14.17	5.76	-2.56	2090
2095	4.701	2.691	2.141	39.82	21.45	14.86	6.31	-2.80	2095
2100	4.968	2.844	2.271	42.32	22.95	15.54	6.89	-3.06	2100