SGM Progress and Development Plan **4 April 2007**

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This attachment provides a topic-by-topic response to the SAB Advisory on the Second Generation Model (SGM). It indicates areas where substantial progress has been made and a plan to address the remaining areas.

The Advisory outlines capabilities that are important for EPA to maintain in order to conduct analysis of alternative climate policies. The SGM already includes many features essential for such analysis and the Advisory recommendations build on those features.

The SGM is not only a modeling framework, but also an analytical tool that captures the collective knowledge of staff from Pacific Northwest National Laboratory (PNNL) and their international collaborators. PNNL staff have been involved with analysis of greenhouse gas emissions over the past 15 years. This collective experience, well over a century in person-years, provides insightful interpretation of model results, assumptions, and data. We have already started to address the recommendations of the Advisory in two fundamental areas: data development and nesting of the production structure. In particular, data from the Global Trade Analysis Project (GTAP) are now the primary data set used for constructing SGM benchmark social accounting matrices. Nested production allows for extended international trade and non-CO_2 greenhouse gas structures.

Part I: Recommended Immediate Improvements

A. Improvements to Documentation

i. General.

This section of the Advisory provides suggestions to improve the organization of model documentation. Documentation for SGM will be updated as model enhancements are completed.

ii. Model Structure.

We agree that further improvements can be made so that model structure is more transparent. A relatively standard way to document computable general equilibrium (CGE) models is to describe model structure in terms of sets, equations, variables, and parameters. This facilitates matching equations with variables, and tracing the sequence of calculations from trial variables provided by the solver to the excess-demand and other system equations handled by the solver.

The Advisory also asks for clarification of the numeraire sector in SGM. Use of GTAP data will provide standardization of production sectors across SGM regions. We agree that an important test of model structure is to show that model output, in terms of quantities, does not depend on the choice of sector as numeraire.

iii. Model Inputs (Data and Parameters)

Many of the recommendations in this section call for a comparison of SGM data to GTAP data. This task is now simplified with the use of GTAP as the primary data set for SGM.

The Advisory also asks for improved documentation of model parameters, especially sources for the parameters. We agree that this part of model documentation should be improved.

iv. Model Outputs and Reporting

The Advisory recommends that some sensitivity analysis be included in model documentation. From working with the model over several years, SGM's developers have a good sense of how changes in model parameters affect baseline projections and model response to a price signal. We agree that these insights should be documented and described in terms of sensitivity analysis.

v. Solution Method

Model documentation can be improved to more fully describe the solution algorithms used in SGM and compare to capabilities provided by commercially available solvers such as in GAMS.

B. Initial Improvements to Data and Parameters

1. The Advisory recommends greater use of GTAP data. We agree and GTAP data, with adjustments, are now the primary data source for SGM. See details in section II.A.ii of this attachment.

2. The Advisory recommends a review of econometric studies of demand elasticities to inform SGM parameters. We agree that the setting of elasticity parameters in SGM should be more closely tied to empirical studies, and that model documentation should describe the sources and assumptions used. In addition, the range of estimates from empirical studies can provide guidance on the variance of these parameters in a sensitivity analysis.

C. Further Sensitivity Analysis

We agree with the Advisory recommendation for a systematic uncertainty analysis. See section II.D of this attachment for plans to address this.

Part II: Recommended Subsequent Improvements

A. Further Improvements to the Data

i. Updating the Data Set

The SGM modeling team is in the process of updating the data set from 1990 to the most recent GTAP base year (2001).

ii. Greater use of GTAP data

The Global Trade Analysis Project (GTAP) at Purdue University provides a global set of social accounting matrices used by trade and environmental modelers throughout the world. However, there are several ways to extend the GTAP data set to make it more suitable for analysis of climate policy. The Advisory states its preferred data development option as "SGM developers use the GTAP data with additional disaggregation of the electricity sector." This is essentially the data development path we are pursuing, with modifications described below.

The data development process for SGM is under revision to (1) take advantage of economic data provided by the Global Trade Analysis Project; (2) allow for timely updates of the model base year; (3) enforce consistency with energy balances published by the International Energy Agency (IEA); and (4) maintain a role for international experts.

For some regions, GTAP is the only source of economic data available to us. The first step is to construct a benchmark input-output table using GTAP, but combine this table with IEA energy balances to restore full consistency with IEA balances and expand the number of energy carriers. After that, national accounts data from GTAP are used to complete a benchmark social accounting matrix for each region. This provides a default or basic benchmark data set for any desired country or aggregation of countries for the GTAP base year, presently 2001. This part of the process is complete and has been automated. Details of this procedure will be presented at the GTAP annual meeting at Purdue University in June 2007.

This basic data set can then be extended in several ways. First, the electricity generating sector can be disaggregated into specific technologies using engineering data. Second, our international collaborators can be called on to compare the GTAP-based data to locally available input-output tables and energy balances. Of particular concern are energy prices and the representation of pre-existing energy taxes or subsidies. There may be further adjustments to the benchmark data set as the result of this comparison to local data.

B. Model Structure Improvements

i. Household Utility Modeling

The Advisory calls for consumer demand to be derived directly from a utility function, which allows for construction of welfare measures and consideration of the labor-leisure and consumption-savings tradeoffs. Common functional forms in CGE models are the Linear

Expenditure System and nested CES utility functions. The consumer demand system in SGM will be replaced and the Linear Expenditure System is a leading candidate. We will also consider adding capability for a nested CES utility function.

ii. Production

A main recommendation of the Panel (page 12 of the Advisory) is to replace the flat (one-level) CES production structure with a nested-CES structure. We agree that this is important and modification is well under way. Specifically, the SGM code is being modified so that a production function can have an arbitrary level of Leontief or CES nests. The actual nesting structure is determined by input data: data for each production function are entered into SGM through an XML tree structure matching the production function nesting structure.

iii. International Trade

The Advisory devotes several pages to international trade (pages 14-17), and provides recommendations for improving the trade structure in a single-region implementation of SGM and for a global version of SGM. Both recommendations rely on the use of the Armington assumption, which distinguishes between imports and domestic production of the same commodity. We agree that the international trade structure in SGM should be modified so that it can be run with Armington assumptions.

The Advisory cites Rutherford et al. (1997) as an example for a single-region implementation. This reference argues that some commodities can be treated on a net-trade basis but that others must be treated as Armington goods. Therefore, we plan to partition inputs to production into three classes: (1) tradable commodities treated on a net-trade basis; (2) Armington commodities; and (3) nontradable commodities. Rutherford et al. (1997) provide a practical approach for the Armington commodities. This approach will be extended to global trade after single-region implementation.

iv. Electricity Sector and Agriculture/Forestry Sectors

Electricity Sector

The electricity sector in SGM already includes a large set of generating technologies. The Advisory provides additional recommendations for improving the ability of SGM to represent policies targeted at this sector.

Rate of capital turnover. The limit of 20 years for the lifetime in SGM capital stocks is simply an artifact of the way SGM was initially coded to handle computer memory limitations. This restriction will be removed.

Regulated prices. The Advisory recommends that the SGM provide a way to allow a shift from peak load to baseload in response to a time-of-use pricing policy. This requires some way to price capacity differently than variable inputs so that a consumer can see both prices.

Policy capabilities. The Advisory recommends that the SGM provide a capability to simulate renewable energy portfolio standards, end-use conservation, and tax incentives favoring particular technologies. A simple way to handle renewable energy standards is to set an exogenous level of generation from renewables. The existing SGM structure for electricity technologies should be able to handle technology-specific subsidies. However, a realistic simulation of end-use programs probably requires construction of a buildings sector with specific end-use subsectors.

Agriculture and Forestry Sectors

The Panel recommends an improved capability for modeling agriculture, land use, and forestry (pages 18-19 in the Advisory). These sectors are important for simulating polices related to carbon sequestration and emissions of methane and nitrous oxide. We are exploring two approaches: both have been discussed in recent meetings of the land use subgroup of the Stanford Energy Modeling Forum (EMF). However, this is a complex topic, and presentations to date at EMF meetings have focused more on methodology than results. It is important for this capability to be applied globally, as declines in food production in one region will likely be offset by increases elsewhere.

The first approach is to extend the nesting structure of agricultural and forestry products to include several land classes in each region. The GTAP group at Purdue University has assembled data to support this approach. Land is treated as a homogeneous resource within each land class.

The second approach is to adapt PNNL's partial equilibrium Agriculture and Land Use model (AgLU) to the general equilibrium setting of SGM. AgLU allocates land to various uses based on a joint probability distribution of productivity or yield over the possible uses of land. Details of the land allocation mechanism are provided in Sands and Leimbach (2003).

In either case, results can be compared to the Forest and Agricultural Optimization Model with greenhouse gases (FASOMGHG) of the U.S. (USEPA, 2005). We have already used output from FASOMGHG exogenously to simulate the contribution of terrestrial greenhouse gas mitigation options at various CO_2 prices and compare that with greenhouse gas mitigation from the energy system (McCarl and Sands, 2007).

v. Non-CO_2_Greenhouse Gas Emissions

The Advisory's main recommendation is to represent emissions mitigation of non-CO_2 greenhouse gases directly in the production structure, where emissions respond to a greenhouse gas price and the cost of emissions reduction is fully reflected in all markets. We agree that this capability should be part of SGM. Several CGE modeling groups use the approach of Hyman et al. (2002), and we plan to add this capability to nested production in SGM.

C. Dealing with Uncertainty

The main recommendation is to use Monte Carlo techniques applied to model parameters, and perhaps even model specification. In a Monte Carlo simulation, the user specifies probability distributions for model parameters, and the model is run repeatedly under different randomly drawn sets of parameters. This provides a way to characterize the probability distribution of policy simulations.

PNNL has experience applying a stochastic front end to a partial-equilibrium energy-economy model (Scott et al., 2000). Here, a Latin Hypercube sampling routine, with an option for specifying covariances, is used to set parameters for each model run. This approach can be adapted to the SGM.

D. Validation through "Backcasting" Exercises

The Advisory contains a short section on backcasting, or starting the model from a point in the past and observing how well the model tracks past history. Such exercises are rare among CGE or integrated assessment modeling teams. An exception is the IMAGE modeling group in the Netherlands.

Backcasting is difficult in part because of the effort required to construct a full benchmark input data set sufficiently in the past to be useful. However, this exercise could be conducted for a single country, such as the United States, where input-output tables and energy balances are available for at least the past 30 years.

References

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