Summary

The MiniCAM is short for Mini-Climate Assessment Model. It is a partial equilibrium, integrated assessment model that examines long term, large scale changes in global and regional energy markets. In particular, it evaluates the energy system, emissions, and other impacts of implementing different technologies. The model accepts input files from the user, processes the data, and produces output. This guide will discuss how to manipulate data for input, run the model, and view model output.

Model Use: Appropriate Model Sensitivity Tests

(The Generation of Energy Demand Scenarios in the ObjECTS MiniCAM)

As with any computer model of real-world systems, some dynamics in the model are captured endogenously (i.e., through the operation of the model) while other dynamics are not explicitly represented and are instead provided as exogenous inputs. Endogenous elements of MiniCAM are represented by both structural models (e.g., the energy system or the agricultural and land use system submodels) and aggregate, reduced-form models (e.g., marginal abatement cost functions for non-CO_2 GHGs). Examples of important exogenous assumptions include energy technology characteristics over time, population and economic assumptions, and the parameters of the Earth system.

Conducting sensitivity tests are a useful method of exercising any model. The MiniCAM is most often used as a tool for examining technology options and their interaction with climate policy and the model is designed to facilitate such exercise. Model experiments examining alternative technology options, energy system structure, climate policies, and physical system parameters (carbon-cycle, climate sensitivity) are, therefore, entirety appropriate for this model. Such experiments can generally be performed by varying these input assumptions. Experiments examining alternative assumptions for population and economic growth, however, *cannot be performed simply by varying these inputs to the model*. This is because these are key drivers that determine end-use energy demands which are captured, to a large degree, through exogenous assumptions. The process for generating end-use energy scenarios within the MiniCAM is described below.

Final energy demands in MiniCAM are the end result of a causal chain from population and related economic output through demands for energy services (to be discussed below) to the energy end use technologies that provide these services. Of course, final energy demands are not independent of the remainder of the energy system, since energy demands are responsive to energy prices which are themselves determined by the costs and performance of energy supply and conversion technologies along with the resource bases for the various energy sources. However, it is the set of inputs and models linking socioeconomic drivers through energy end use technologies that are the fundamental building blocks of a final energy demand scenario.

The next several paragraphs walk through several of the initial steps in the process of creating an energy demand system for use in MiniCAM. The first step is the creation of an underlying socioeconomic scenario. Such a scenario requires a time path for three parameters in each of MiniCAM's 14 regions: (1) population (or population growth), (2) labor force participation, and (3) labor force productivity (or labor force productivity growth). Together, these three parameters, supplied exogenously to MiniCAM, lead to time paths of economic output in each of

MiniCAM's 14 regions. Note that MiniCAM includes an energy price feedback to GDP growth, but the core foundation of economic growth is laid through these three parameters.

The next step is to define the energy service demands associated with this time path of economic activity. Energy services represent the outputs from energy that consumers and businesses consume. Consumers and businesses do not demand electricity, natural gas, and gasoline for their intrinsic value; they demand heating, lighting, car travel, so forth, and these fuels, along with associated equipment, are inputs to produce these energy services.

In understanding the role and characterization of energy service demands, it is important to understand the distinction between aggregate and detailed end use sectors in MiniCAM. In the aggregate end-use version of the MiniCAM, each of MiniCAM's 14 regions is characterized by demands for three aggregate energy services: industrial energy services, building energy services, and transportation energy services. These aggregate energy service serve as an indexed proxy for the multitude of individual services that energy fuels in each of these sectors, for example, heating, cooling, lighting, cooking, and so forth in buildings, or passenger- or tonne-miles in transportation. In this aggregate approach, the energy service is an aggregation of all these energy services, meaning that no single real-world unit of measure can be used to express it. Instead, an index is used, and this index grows over time in response to increases in economic activity, as will be discussed below.

Recently, a capability has been created in MiniCAM for substantially more detailed end use sectors that break out the individual energy service demands in each sector. For example, the detailed building sector tracks floor space and then associates demands for heating, cooling, lighting, and so forth with this increasing floor space. This greater detail allows for representation of energy services in actual physical units, such as therms of heating, lumens of cooling, or passenger miles. A set of detailed end-use sectors have been implemented for the U.S., and current research is exploring opportunities to expand detailed end use representations into other key regions. Because of its modular structure, MiniCAM can implement both detailed and aggregate sectors, in different regions, in a single model run.

In both the aggregate and the detailed sectors, energy service demands are typically correlated to service prices and to income through a constant elasticity formulation:

$$d = \alpha\, i^{\mu} P^{\rho} \tag{1}$$

where d is service demand per capita, i is per capita income, and P is the aggregate price of the service. The other independent variables are parameters of the equation. This functional form holds whether the energy service is an aggregation of multiple energy services, or a specific energy-related service such as floorspace.

Constant elasticity based formulations of demand have proven extraordinarily valuable for economic analysis. However, they are best suited for analyses that consider small variations from existing conditions. When the deviation from current conditions is large, the constant elasticity formulation can break down. For example, if service demands were simply to rise exponentially with income, the average citizen of a wealthy country might be spend more time in travel than reasonably available in an average day. In other words, some energy service demands may saturate at higher income levels. Given that MiniCAM and similar models must look a century or more into the future, this is a limitation of the constant elasticity relationship between income and service demands.

Hence, in the construction of MiniCAM final energy scenarios, the approach used by MiniCAM modelers, in cases where saturation seems likely, is to construct a path that replicates a set of energy service to income relationships that show this saturation. MiniCAM modelers create a relationship between per-capita GDP and per-capita service for each of the model's 14 regions. These relationships can then be replicated through a variety of mechanisms, including the use of a time varying income elasticity, changes to an autonomous energy end-use efficiency, or through off-line solution of supply-demand relationships.

There is one important limitation to this approach, and one that may be addressed in future model improvements by placing these service demand relationships directly into the model rather than approximating them using, for example, a time-varying elasticity path. Changes in the underlying socioeconomics, for example, through a sensitivity analysis, will break the link between per-capita service demands and per-capita income, because the changing elasticities used to capture saturation are linked to time and not directly to per-capita income. If the per-capita income path changes, but the income elasticity path remains constant, the final energy scenarios will not follow consistent per-capita service to per-capita income relationships. This limitation would be eliminated if include explicit representations of the per-capita service to per-capita income relationships are included. Until that time, **development of socioeconomic and service demand scenarios must be done simultaneously**. Sensitivities looking only at socioeconomic drivers should not be attempted and could produce nonsensical results.

The next step in the development of final energy demands is the specification of improvements over time in energy demand technologies. In the aggregate model, these technological improvements are represented through two levers. The first is an aggregate energy intensity improvement parameter for each sector, which can also embody some aspect of changing relationships between income and energy demands. The second lever is the efficiencies of representative end use technologies. In the aggregate version of MiniCAM, a generic technology is associated with each fuel used by each sector, for example, one hydrogen technology, one gasoline technology, one electric technology, and so forth to provide transportation energy services. Over time, changes in these inputs will affect not only total energy demand, but also the distribution between fuels.

In the detailed end use models, these technologies correspond to specific real-world technologies, such as an electric heat pump or a passenger car using an internal combustion engine. In these cases, researchers developing scenarios must develop meaningful time paths for the changes in cost and performance of these technologies over time. In addition, scenarios of increasing saturation of particular energy services, such as air conditioning, can be created using saturation parameters associated with those particular services.