A COMPARISON OF THE TIMES AND MARKAL MODELS

This note is taken from the times documentation and it contains a point-by-point comparison of the TIMES and MARKAL models. It is of interest primarily to modelers already familiar with MARKAL, and to modelers who are considering adoption of either model. The descriptions of the features given below are not detailed, since they are repeated elsewhere in the documentation. Rather, the function of this chapter is to guide the reader, by mentioning the features that are present in one model and not in the other.

SIMILARITIES

The TIMES and the MARKAL models share the same basic modeling paradigm. Both models are technology explicit, dynamic partial equilibrium models of energy markets. In both cases the equilibrium is obtained by maximizing the total surplus of consumers and suppliers via Linear Programming. The two models also share the multi-regional feature, which allows the modeler to construct geographically integrated (even global) instances.

These fundamental features were described in chapter 3 of this documentation, and Section 1.3, PART I of the MARKAL documentation, and constitute the backbone of the common paradigm. However, there are also significant differences in the two models, which we now outline. These differences do not affect the basic paradigm common to the two models, but rather some of their technical features and properties.

TIMES FEATURES NOT IN MARKAL

VARIABLE LENGTH TIME PERIODS

MARKAL has fixed length time periods. However TIMES allows the user to define period lengths in a completely flexible way. This is a major model difference, which indeed required a complete re-definition of the mathematics of most TIMES constraints and of the TIMES objective function. The variable period length feature is very useful in two instances: first if the user wishes to use a single year as initial period (handy for calibration purposes), and second when the user contemplates long horizons, where the first few periods may be described in some detail by relatively short periods (say 5 years), while the longer term may be regrouped into a few periods with long durations (perhaps 20 or more years).

DATA DECOUPLING

This somewhat misunderstood feature does not confer additional power to TIMES, but it greatly simplifies the maintenance of the model database and allows the user great flexibility in modifying the new definition of the planning horizon. In TIMES all input data are specified by the user independently from the definition of the time periods employed for a particular model run. All time-dependent input data are specified by the year in which the data applies. The model then takes care of matching the data with the periods, wherever required. If necessary the data is interpolated (or extrapolated) by the model preprocessor code to provide data points at those time periods required for the current model run. In addition, the user has control over the interpolation and extrapolation of each time series.

The general rule of data decoupling applies also to past data: whereas in MARKAL the user had to provide the residual capacity profiles for all existing technologies in the initial period, and over the periods in which the capacity remains available, in TIMES the user provides technical and cost data at those past years when the investments actually took place, and the model takes care of calculating how much capacity remains in the various modeling periods. Thus, past and future data are treated essentially in the same manner in TIMES. One instance when the data decoupling feature immensely simplifies model management is when the user wishes to change the initial period, and/or the lengths of the periods. In TIMES, there is essentially nothing to do, except declaring the dates of the new periods. In MARKAL, such a change represents a much larger effort requiring a substantive revision of the database.

FLEXIBLE TIME SLICES AND STORAGE PROCESSES

In MARKAL, only two commodities have time-slices: electricity and low temperature heat, and their time slices are rigidly defined (six time-slices for electricity and three for heat). In TIMES, any commodity and process may have its own, user-chosen time-slices. These flexible time-slices are segregated into three groups, seasonal (or monthly), weekly (weekday vs weekend), and daily (day/night), where any level may be expanded (contracted) or omitted. The flexible nature of the TIMES time-slices is supported by storage processes that 'consume' commodities at one time-slice and release them at another. MARKAL only supports night-to-day (electricity) storage. Note that many TIMES parameters may be time-slice dependent (such as availability factor (AF), basic efficiency (FLO_FUNC), etc).

PROCESS GENERALITY

In MARKAL processes in different RES sectors are endowed with different (data and mathematical) properties. For instance, end-use processes do not have activity variables (activity is then equated to capacity), and source processes have no investment variables. In TIMES, every process has the same basic features, which are activated or not solely via data specification.

FLEXIBLE PROCESSES

In MARKAL processes are by definition rigid, except for some specialized processes which permit flexible output (such as limit refineries or pass-out turbine CHPs), and thus outputs and inputs are in fixed proportions with one another. In TIMES, the situation is reversed, and each process starts by being entirely flexible, unless the user specifies certain coefficients to rigidly link inputs to outputs. This feature permits better modeling of many real-life processes as a single technology, where MARKAL requires several technologies (as well as dummy commodities) to achieve the same result. A typical example is that of a boiler that accepts any of 3 liquid fuels as input, but whose efficiency depends on the fuel used. In MARKAL, to model this situation requires four processes (one per possible fuel plus one that carries the investment cost and other parameters), plus one dummy fuel. In TIMES one process is sufficient, and no dummy fuel is required. Note also that TIMES has a number of parameters that limit the input share of each fuel, whereas in MARKAL, imposing such limits requires that the user define several user constraints.

INVESTMENT AND DISMANTLING LEAD-TIMES AND COSTS

New TIMES parameters allow the user to model the construction phase and dismantling of facilities that have reached their end-of-life. These are: lead times attached to the construction or to the dismantling of facilities, capital cost for dismantling, and surveillance costs during the dismantling lead-time. Like in MARKAL, there is also the possibility to define flows of commodities consumed at construction time, or released at dismantling times, thus allowing the representation of life-cycle energy and emission accounting.

VINTAGED PROCESSES AND AGE-DEPENDENT PARAMETERS

The variables associated with user declared vintaged processes employ both the time period p and vintage period v (in which new investments are made and associated input data is obtained). The user indicates that a process is to be modeled as a vintaged process by using a special vintage parameter. Note that in MARKAL vintaging is possible only for demand devices (for which there is no activity variable) or via the definition of several replicas of a process, each replica being a different vintage. In TIMES, the same process name is used for all vintages of the same process.

In addition, some parameters can be specified to have different values according to the age of the process. In the current version of TIMES, these parameters include the availability factors, the in/out flow ratios (equivalent to efficiencies), and the fixed cost In the end the two models use equivalent mathematical expressions to represent a flexible process. Only TIMES reduces the user’s effort to a minimum, while MARKAL requires the user to manually define the multiple processes, dummy fuels and user constraints.

The representation of vintage as a separate index helps eliminate a common confusion that existed in MARKAL, namely the confusion of vintage with the age of a process. For instance, if the user defines an annual cost for a car equal to 10 in 2005 and only 8 in 2010, the decrease would not only apply to cars purchased in 2010, but also to cars purchased in 2005 and earlier when they reach the 2010 period. Several other parameters could, in principle, be defined to be age-dependent, but such extensions have not been implemented yet.

COMMODITY RELATED VARIABLES

MARKAL has very few commodity related variables, namely exports/imports, and emissions. TIMES has a large number of commodity-related variables such as: total production, total consumption, but also specific variables representing the flows of commodities entering or exiting each process. This allows the user many “handles” to put limits, and costs on commodities.

MORE ACCURATE AND REALISTIC DEPICTION OF INVESTMENT COST PAYMENTS

In MARKAL each investment is assumed to be paid in its entirety at the beginning of some time period. In TIMES the timing of investment payments is quite detailed. For large facilities (e.g. a nuclear plant), capital is progressively laid out in yearly increments over the facility’s construction time, and furthermore, the payment of each increment is made in installments spread over the economic life of the facility. For small processes (e.g. a car) the capacity expansion is assumed to occur regularly each year rather than in one large lump, and the payments are therefore also spread over time. Furthermore, when a time period is quite long (i.e. longer that the life of the investment), TIMES has an automatic mechanism to repeat the investment more than once over the period. These features allow for a much smoother (and more realistic) representation of the stream of capital outlays in TIMES than in MARKAL. Moreover, in TIMES all discount rates can be defined to be time-dependent, whereas in MARKAL both the general and technology-specific discount rates are constant over time.

CLIMATE EQUATIONS

TIMES now possesses a set of variables and equations that endogenize the concentration of CO_2 and also calculate the radiative forcing and global temperature change resulting from GHG emissions and accumulation in the atmosphere. This new feature is described in chapter 7 of PART II.