Energy Technology Systems Analysis Programme

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Documentation for the TIMES Model

PART III

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General Introduction to the TIMES Documentation

This documentation is composed of five Parts.

Part I provides a general description of the TIMES paradigm, with emphasis on the model's general structure and its economic significance. Part I also includes a simplified mathematical formulation of TIMES, a chapter comparing it to the MARKAL model, pointing to similarities and differences, and chapters describing new model options.

Part II constitutes a comprehensive reference manual intended for the technically minded modeler or programmer looking for an in-depth understanding of the complete model details, in particular the relationship between the input data and the model mathematics, or contemplating making changes to the model's equations. Part II includes a full description of the sets, attributes, variables, and equations of the TIMES model.

Part III describes the organization of the TIMES modeling environment and the GAMS control statements required to run the TIMES model. GAMS is a modeling language that translates a TIMES database into the Linear Programming matrix, and then submits this LP to an optimizer and generates the result files. Part III describes how the routines comprising the TIMES source code guide the model through compilation, execution, solve, and reporting; the files produced by the run process and their use; and the various switches that control the execution of the TIMES code according to the model instance, formulation options, and run options selected by the user. It also includes a section on identifying and resolving errors that may occur during the run process.

Part IV provides a step-by-step introduction to building a TIMES model in the VEDA model management software. It first offers an orientation to the basic features of VEDA, including software layout, data files and tables, and model management features. It then describes in detail twelve Demo models (available for download from the ETSAP website) that progressively introduce VEDA-TIMES principles and modeling techniques. It also provides a guide to results processing, including how to create and view results tables, and to create and modify user-defined sets.

PART III: THE OPERATION OF THE TIMES CODE

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1 Introduction

1.1 Summary of components

The TIMES model environment under VEDA is depicted in Figure 1. For ANSWER the underlying model management flow is very similar, with the addition of a <Case>.ANT file being dumped by the TIMES GAMS report writer for importing of the model results into ANSWER, if desired, though model TIMES users tend to rely on the extra power brought to bear by VEDA-BE.

It is composed of five distinct components described below.

- **The TIMES Model Generator** (as well as **MARKAL**[1]) comprises the GAMS source code that processes each dataset (the model) and generates a matrix with all the coefficients that specify the economic equilibrium model of the energy system as a mathematical programming problem. The model generator also post-processes the optimization to prepare results that are suitable to be read by the model management systems (and other tools). It is shown in Figure 1 labelled as TIMES. The TIMES model generator is available from ETSAP under an open source license[2].

- **The model** is a set of data files (spreadsheets, databases, simple ASCII files), which fully describes an energy system (technologies, commodities, resources, and demands for energy services) in a format compatible with an associated model management shell. Each set of files comprises one model (perhaps consisting of a number of regional models) and is "owned" by the developer(s). It is shown in Figure 1 as the Data and Assumptions box in the upper left. Instances of global models include the IEA's Energy Technology Perspectives (ETP[3]), the TIMES Integrated Assessment Models (TIAM[4]), and that of the European Fusion Development Agreement (EFDA[5]). Large multi-region models exist in the form of Pan-European TIMES models (JRC-EU-TIMES[6] and PET[7]) covering all EU member states (+ Norway, Switzerland and Iceland in the PET model), and the Framework for Analysis of Climate-Energy-Technology Systems (FACETS[8]) for the US. Finally, there are numerous national, regional, and municipal models developed by the ETSAP Partner institutions and other institutions.[9,10]

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[1] MARKAL is the legacy ETSAP model generator superseded by its advanced TIMES successor.
[2] https://iea-etsap.org/index.php/etsap-tools/acquiring-etsap-tools
[3] http://www.iea.org/etp/etpmodel/
[4] https://iea-etsap.org/index.php/applications/global
[5] https://www.euro-fusion.org/wpcms/wp-content/uploads/2015/02/EFDA-TIMES_Global.pdf
[6] https://iea-etsap.org/index.php/applications/regional
[7] http://www.kanors-emr.org/Website/Models/PET/Mod_PET.asp
[8] http://facets-model.com/overview/
[9] https://iea-etsap.org/index.php/applications/national
[10] https://iea-etsap.org/index.php/applications

- **A Model Management "shell"** is a user interface that oversees all aspects of working with a model, including handling the input data, invoking the Model Generator, and examining the results. It is shown in Figure 1 labelled VEDA-FE and VEDA-BE for the parts handling the input data and model results respectively. It thereby makes practical the use of robust models (theoretically, simple models can be handled by means of ASCII file editors, if desired). The first shell, MUSS, was developed in 1990 by DecisionWare Inc. for use with MARKAL (and is no longer available). Two shells currently in use for TIMES are ANSWER, originally developed by ABARE and subsequently the property of Noble-Soft Systems Pty Ltd[11], and VEDA, developed by KanORS-EMR. Both ANSWER and VEDA handle MARKAL as well as TIMES. Both shells were partly developed using ETSAP resources, along with substantial contributions of the developers and other projects employing the systems. Note that as shown in Figure 1, VEDA-FE interacts with GAMS by means of the *.RUN/DD files and GAMS interacts with VEDA-BE by processing the GDX file to produce the run VD* files. VEDA-BE can write to XLS or other file types. See Sections IV and V for a description of VEDA, and the separate ANSWER documentation respectively.

- **The General Algebraic Modeling System (GAMS)**[12] is the computer programming language in which the MARKAL and TIMES Model Generators are written. GAMS is a two-pass language (first compiling the input data and source code, then executing for the data provided) designed explicitly to facilitate the formulation of complex mathematically programming models. GAMS integrates smoothly with various solvers to generate the mathematic programming problem and seamlessly pass it to the solvers for optimization, then post-process the optimization to produce the TIMES results report for the "shells." It is shown in Figure 1 GAMS together with the final component, Solvers. During a run, GAMS produces a LST file with an echo of the model run steps and solution. The LOG file in the figure is actually produced by TIMES, listing the quality assurance checks. GAMS is the property of GAMS Development Corporation, Washington D.C. Information on GAMS may be found at www.gams.com. More specific GAMS - ETSAP information can be obtained from the ETSAP Liaison Officer, Gary Goldstein.

- **A solver** is a software package integrated with GAMS which solves the mathematical programming problem produced by the Model Generator for a particular instance of the

[11] Note that as of December 2016 ANSWER will no longer be actively developed and only limited support will be provided, so although mentioned here in Part III, users should carefully consider their longer-term needs when considering using ANSWER as their TIMES model management platform going forward.

[12] Anthony Brooke, David Kendrick, Alexander Meeraus, and Ramesh Raman, GAMS – A User's Guide, December 1998, www.gams.com.

TIMES model. Solvers are discussed further in Section 1.4. More information on solvers may be found at www.gams.com.

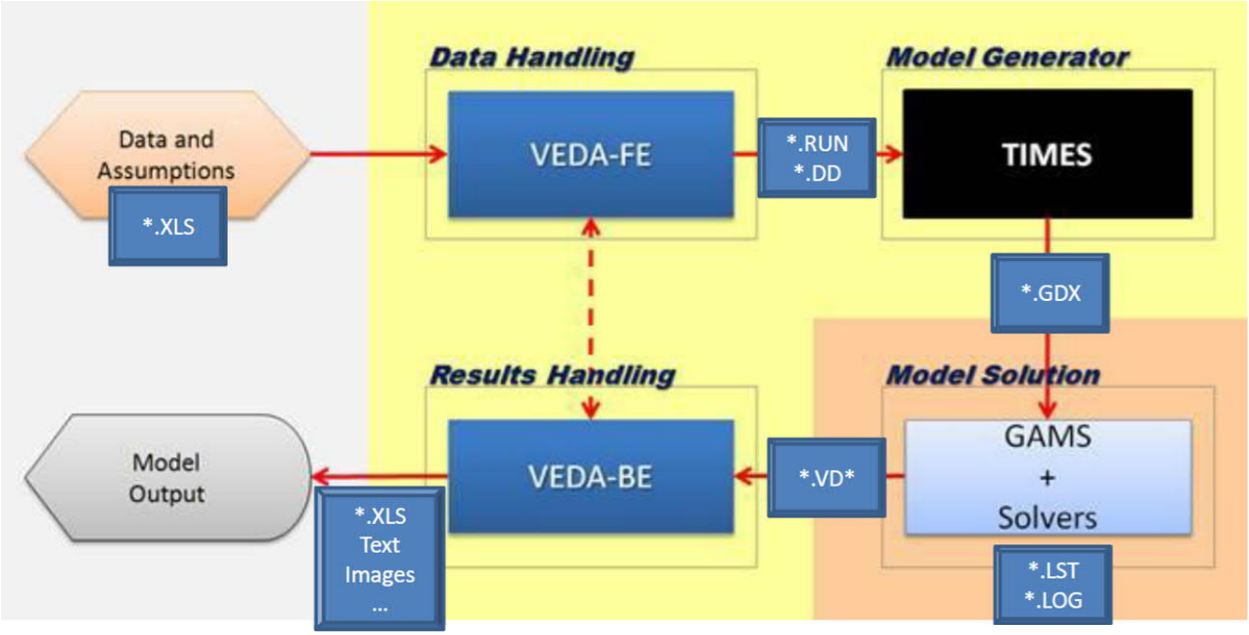


Figure 1: Components of the TIMES Modeling Platform Under VEDA

The rest of this Part describes in more detail how the computer environment is organized and operates to make working with TIMES viable and effective.

1.2 Minimum computer requirements

The minimum basic software requirements consist of the GAMS modeling language and an associated solver, a model management "shell" (which while technically optional has been used for every application of TIMES to date) comprised of either VEDA (Front-End (FE) for handling input data and Back-End (BE) for processing results) or ANSWER (where ANSWER users often also employ VEDA-BE for results). The "shells" are Windows based Visual-Basic turnkey applications that are distributed as part of a TIMES installation package, see Parts IV and V for VEDA and the separate ANSWER documentation for a discussion on the model management systems.

In terms of the Windows operating system, any version (32 or 64 bit) from Version 7 on is supported by both ANSWER and VEDA. Both ANSWER and VEDA require that a properly licensed version of Microsoft Excel be installed on the computer. Both shells may be run on Apple computers within a Windows emulator; however, they are not supported on Linux/Unix platforms.

For hardware, a "high-end" personal computer with a minimum of 8GB RAM (16GB or more for larger models), ideally a multi-core/CPU processor (dual quad core for large models),

and up to 250GB (depending upon the size of the model and studies to be undertaken) of hard disk storage for the modeling is recommended.

1.3 General layout of the software

Each of the components mentioned above – GAMS, VEDA, and ANSWER – reside in their own Windows folder of the **ROOT** on whatever drive the user wishes. When installing the software, the user is strongly encouraged to follow this "install in the root" recommendation, as the complex nature of the software systems and their interdependencies are most smoothly handled when the system is setup in this manner (rather than installing under Program Files for example).

The various components discussed above "talk" with each other primarily by means of ASCII text files deposited in common locations (folders) and passed between said components. The specific folder layout for each component is discussed below and later in the Section a look at the specific files involved with the inter-component communication is provided. This handshaking is virtually seamless from the users' perspective, as long as all the component paths are properly identified for each component.

For GAMS, the system is self-contained in a \GAMS\<os>\<version> system folder (if installed in the default location, as recommended) and is connected to VEDA-FE and ANSWER through the Windows Path Environment Variable. This GAMS path is either set during installation automatically (by requesting Advanced Installation Mode and requesting Add GAMS Directory to Path Environment Variable) or manually via the Windows Control Panel. Full (simple) instructions are provided for installing and properly configuring GAMS for use with TIMES with the software distribution notification email and are summarized in Section 1.4 below.

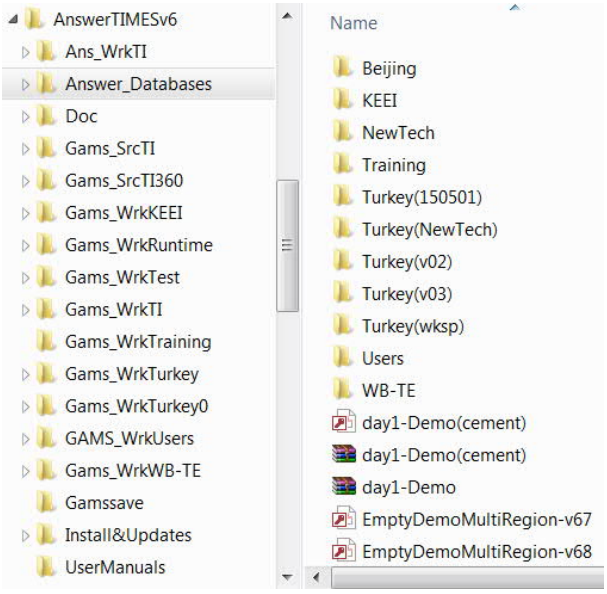


Figure 2: Layout of the ANSWER Folders

For ANSWER, the core of the system must reside in a single folder \AnswerTIMESv6 (encouraged to be right off the root). A full description of the folder structure that ANSWER employs may be found in the separate ANSWER documentation, with the basic layout shown in Figure 2 below. From the perspective of connecting ANSWER with GAMS and VEDA-BE (if used) the key subfolders the user needs to be aware of are the GAMS_SrcTI and GAMS_WrkTI default TIMES source code and model run folders respectively. Upon initiating a model run, ANSWER needs to inform GAMS where the TIMES model source code is, that being GAMS_SrcTI (or any variant the user chooses to setup). For the model results to find their way to VEDA-BE, it must be informed of the model run folder, that being GAMS_WrkTI (or any

variant the user chooses to set up, say for different projects), through the VEDA-BE Import Results/Manage Input File Location operation. The location of these folders for each model is set within ANSWER, through the Tools/File Locations option. (In the example shown in Figure 2, several GAMS_Wrk<model> folders have been created so that different models (or projects) are run in distinct folders.)The other folder the user will interact with is the Answer_Databases where by default the user's ANSWER TIMES database (MDB) and usually Excel input templates would reside. In this regard the user is encouraged to make subfolders under Answer_Databases (or any other location they wish) for each of their models or project, as shown in Figure 2.

For VEDA, the core of the system must reside in a single folder \VEDA (encouraged to be right off the root), with the basic required folder structure shown in Figure 3. From the perspective of connecting VEDA-FE with GAMS, the key subfolders the user needs to be particularly aware of are the GAMS_SrcTIMESv### and GAMS_WrkTIMES (or other run folders for each project if desired), the default TIMES source code and model run folders respectively. Both reside in the \VEDA\VEDA_FE folder. Upon initiating a model run, VEDA-FE needs to inform GAMS where the TIMES model source code is, that being GAMS_SrcTIMES### (or any variant the user chooses to setup). For the model results to find their way to VEDA-BE it must be informed of the model run folder, that being GAMS_WrkTIMES (or any variant the user chooses to set up, say for different projects or model instances), through the VEDA-BE Import Results/Manage Input File Location operation. The location of these folders for each model is set within VEDA-FE, through Tools/User Options settings.

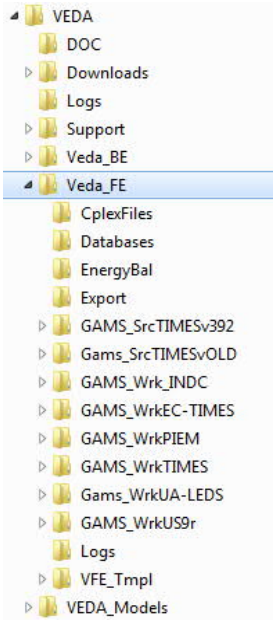


Figure 3: Layout of the VEDA-FE Folders

To complete the inter-connection picture between components of VEDA, VEDA-FE maintains each model instance in the VEDA_Models folder where the user assembles the model input Excel templates. The other folder the user will need to be aware of is the VEDA_BE\Databases\<project> where the user's the VEDA-BE results databases reside. In order for VEDA-FE to use Sets defined in VEDA-BE for user constraint and/or scenario specifications, the former must be pointed to the latter – by means of clicking on the VEDA-BE database reference up at the top of the VEDA-FE application window.

1.4 Software installation

This section provides an overview of the installation process for GAMS, which is required for all TIMES installations[13]

GAMS employs "soft" licensing. That is, each system is licensed for a certain Windows PC or Server or Linux and requested solvers to a particular institution for a requested number of users. The license is not to be shared outside the authorized institution and the number of users is to be adhered to – all based upon trust (and the very active GAMS and MARKAL/TIMES user community).

Note that GAMS provides two kinds of licenses for working with TIMES, the conventional license which provides the user with the actual TIMES GAMS source code, and a Runtime license where the source code is precompiled and therefore may not be changed. The Runtime license ONLY permits GAMS to be used in conjunction with TIMES. That is, no other GAMS models may be run using a ETSAP TIMES Runtime license. The Runtime license is sold at half the price of a corresponding full license. To obtain GAMS for use with MARKAL/TIMES contact the ETSAP Liaison Officer, Gary Goldstein.

The basic procedure for installing GAMS is:

1. Copy your GAMS license file, GAMSLICE.txt, provided as part of the licensing process by the Liaison Officer, someplace on your computer.
2. Head to http://www.gams.com/download/ and select the Windows download option for either Win-64/32, as appropriate.
3. Run Setup by clicking on it in Windows Explorer
    a) Check "Use advanced installation mode" at the bottom of the GAMS Setup form.
    b) Let GAMS get installed into the default folder (\GAMS\<Win#>\<ver>.
    c) Check the Add GAMS directory to PATH environment variable.
    d) Have the GAMSLICE.TXT copied from wherever it currently resides.

If you are using a non-default solver (e.g., CPLEX is the default for LP and MIP models and CONOPT for NLP) then there is one further step that must be carried out to complete the setup procedure:

4. If using a non-default solver, upon completion use Windows Explorer to go to the GAMS system folder and run the GAMSINST program to set the default solver for each type to the solvers supported by your license GAMSLICE file by entering the associated number in the list and hitting return or just hitting return (if your solver is the default or not listed).

Which solver to use is a function of the TIMES model variant to be solved and the solver(s) purchased by the user with GAMS. Basically the solvers used for TIMES fall into three

[13] Instructions for installing VEDA are available at http://support.kanors-emr.org/VEDAInstallation. Instructions for ANSWER can be obtained from Noble-Soft Systems.

categories, linear (LP), mixed integer (MIP) and non-linear (NLP), where Table 1 provides a partial list of the GAMS solvers generally used with TIMES for each main model variant. For a complete list of the solvers available refer to the GAMS website. The various Model Instances mentioned in the table are discussed further in Section 3.6, as well as in Parts I and II.

Table 1: TIMES Model Variants and GAMS Solvers

Model Instance	Nature of Model	Viable Solvers
Basic TIMES (including Elastic Demand, Climate, Stochastic, etc.)	Linear (LP)	For full-blown TIMES models power solvers are recommended (CPLEX/XPRESS/GUROBI) For modest size models MINOS or the "free" public solvers may suffice
Discrete Investment, Discrete Retirement, Discrete Dispatching and Endogenous Technology Learning Extensions	Mixed Integer (MIP)	Power solvers are recommended (CPLEX/XPRESS/GUROBI) For modest size models the "free" public CBC solvers may suffice
MACRO (integrated or MSA/CSA), Micro (NLP option), Damage (NLP option)	Non-linear (NLP)	CONOPT recommended, MINOS an option (but no longer being developed)

1.5 Organization of Part III

Section 2 lays out more specifically how the various components of the TIMES modeling platform interact and accomplish their tasks. Following an overview of the run process, the routines comprising the TIMES source code are described, discussing how they guide the model through compilation, execution, solve, and reporting. Section 2.3 then describes the various files produced by the run process and their use. Finally, Section 2.4 discusses identifying and resolving errors that may occur during the run process. Section 3 then details the various switches that control the execution of the TIMES code.

2 The TIMES source code and the model run process

As discussed in the previous section, the heart of TIMES is embodied in the GAMS source code, comprised of the matrix generator that digests the input data prepared from ANSWER or VEDA-FE and prepares the mathematical representation of the model instance, an optimizer to solve the resulting mathematical programming problem, and a report writer that post-processes the solution and prepares results files for ANSWER and VEDA-BE. It is this collection of GAMS source code routines that correspond to the TIMES model, where each TIMES model run

proceeds through the appropriate path in the source code based upon the user specified runtime switches, described in Section 3, and the provided input data.

For the most part, this process is seamless to the user, as the model management shells extract the scenario data and prepare ASCII text files in the layout required by GAMS, set up the top level GAMS control file, and initiate the model run (in a Command Prompt box). GAMS then compiles the source and data, constructs the model, invokes the solvers, and dumps the model results for importing back into the model management environment. However, knowledge of the run process and the files produced along the way can be helpful in diagnosing model errors (e.g., a division by zero may necessitate turning on the source code listing ($ONLISTING/$OFFLIST at the top/bottom of the routine where the error is reported) to determine which parameter is causing the problem) or if a user is considering modifying the model formulation to, say, add a new kind of constraint (note that any such undertaking should be closely coordinated with ETSAP).

2.1 Overview of the model run process

Once a model is readied, a run can be initiated from the model management systems by means of the Case Manager in VEDA-FE or the Run Model option on the ANSWER Home screen. In both systems the user assembles the list of scenarios to comprise the model run, taking care to ensure that the order of the scenarios is such that all RES components are first declared (that is their item name and set membership specified) and then assigned data.

In the model management shells, the user can also adjust the TIMES model variant, run control switches, and solver options. For VEDA-FE this is done through the Case Manager, via the Control Panel, RUNFile template, and solver settings. Figure 4 shows an example of the VEDA-FE Control Panel. See Part IV for more on the use of the Case Manager in VEDA-FE.

In ANSWER, the Run Model button brings up the Run Model Form, from which the model variant and most run control switches can be set. (The others need to be set using the Edit GAMS Control Options feature.) However the <Solver>.OPT file needs to be handled manually outside of ANSWER. See the separate ANSWER documentation for more details on these ANSWER facilities.

When a model run is initiated, three kinds of files are created by VEDA and ANSWER. The first is a Windows command script file VTRUN/ANSRUN.CMD (for VEDA/ANSWER respectively), which just identifies the run name, indicates where the source code resides, and perhaps any restart (see Section 3.8), and then calls the VEDA/ANSWER driver command script (VT_GAMS/ANS_RUN.CMD). The second is the top-level GAMS command file <Case>.RUN/GEN (for VEDA/ANSWER), which is passed to GAMS to initiate and control the model run. It sets the model variant, identifies the Milestone (run) years, lists the scenario data files (DD/DDS) to include, and invokes the main GAMS routine to have the model actually assembled mathematically, solved, and reported upon. It is discussed further in Section 2.3.1. The third group of files comprise the data dictionary <scenario>.DD/DDS file(s), which contain the user input sets and parameters in the format required by GAMS to fully describe the energy system to be analyzed.

GAMS is a two pass language, first compiling and then executing. In the first pass, GAMS reads the input data prepared by ANSWER or VEDA-FE, and then proceeds to compile the data as well as the actual TIMES source code to ready it for execution (unless a Runtime license is employed in which case only the data is compiled).

In the second pass, GAMS then proceeds to execute the complied data and code to declare the equations and variables that are to make up this particular TIMES incarnation and generate the appropriate coefficients for matrix intersection, that is the multiplier for the individual variables comprising each equation. With the matrix assembled GAMS then turns over the problem to the solver.

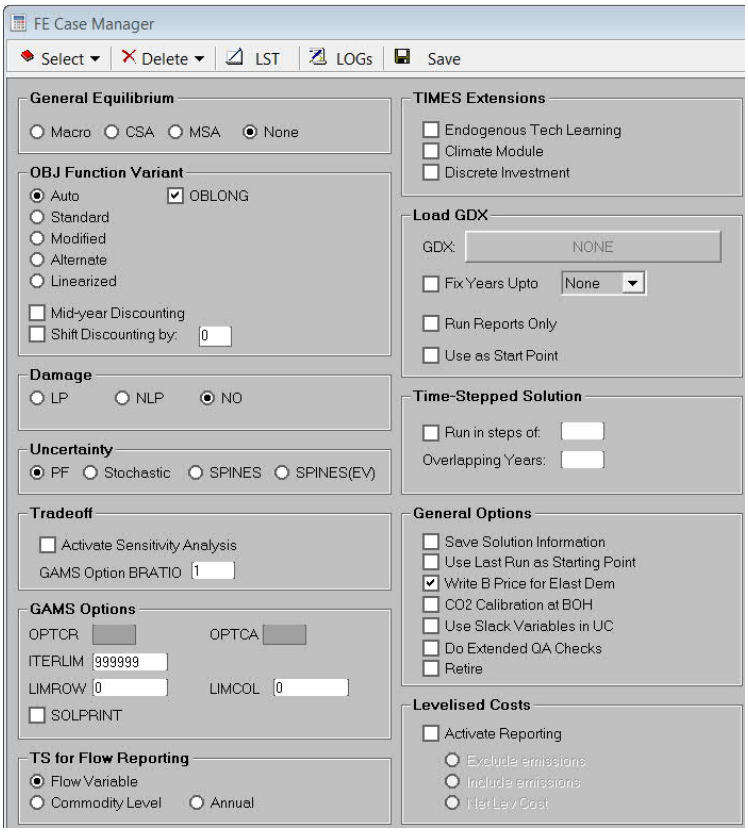


Figure 4: VEDA-FE Case Manager Control Form

As a result of a model run a listing file (<Case>.LST), and a <case>.GDX file (GAMS dynamic data exchange file with all the model data and results) are created. The <Case>.LST file may contain compilation calls and execution path through the code, an echo print of the GAMS source code and the input data, a listing of the concrete model equations and variables, error messages, model statistics, model status, and solution dump. The amount of information displayed in the listing file can be adjusted by the user through GAMS options in the <Case>.RUN file.

The <Case>.GDX file is an internal GAMS file. It is processed according to the information provided in the TIMES2VEDA.VDD to create results input files for the VEDA-BE software to

analyze the model results in the <case>.VD* text files. A dump of the solution results is also done to the <case>.ANT file for importing into ANSWER, if desired. At this point, model results can be imported into VEDA-BE and ANSWER respectively for post-process and analysis. More information on VEDA-BE and ANSWER results processing can be found in Part V and the separate ANSWER documentation respectively.

In addition to these output files, TIMES may create a file called QA_CHECK.LOG to inform the user of possible errors or inconsistencies in the model formulation. The QA_CHECK file should be examined by the user on a regular basis to make sure no "surprises" have crept into a model. The content and use of each of these files is discussed further in Section 2.3.

For the ETSAP Runtime GAMS license, which does not allow for adjustments to the TIMES source code by users (which in general is not encouraged anyway), a special TIMES.g00 file is used that contains the declaration of each variable and equation that is part of the model definition, thereby initializing the basic model structure.

2.2 The TIMES source code

The TIMES model generator is comprised of a host of GAMS source code routines, which are simple text files that reside in the user's \VEDA\VEDA-FE\GAMS_SrcTIMESv### folder, as discussed in Section 1.3 (or \AnswerTIMESv6\GAMS_SrcTI). Careful naming conventions are employed for all the source code routines. These conventions are characterized, for the most part, by prefixes and extensions corresponding to collections of files handling each aspect of the code (e.g., set bounds, prepare coefficients, specify equations), as summarized in Table 2.

Table 2: TIMES Routines Naming Conventions

Type	Nature of the Routine
Prefix	
ans	ANSWER TIMES specific pre-processor code
bnd	set bounds on model variables
cal	calculations performed in support of the preprocessor and report writer
coef	prepare the actual matrix intersection coefficients
eq	equations specification (the actual assembling of the coefficients of the matrix)
err	Error trapping and handling
fil	handles the fundamental interpolation/extrapolation/normalization of the original input data
init	initialize all sets and parameters potentially involved in assembling a TIMES model
main	Top level routines according to the model variant to be solved
mod	the declaration of the equations and variables for each model variant
pp	preprocess routines responsible for preparing the TIMES internal parameters by

Type	Nature of the Routine
	assembling, interpolating, levelizing, normalizing, and processing the input data to prepare the data structures needed to produce the model coefficients
qa	Quality assurance checking and reporting
rpt	main reporting components performing the calculations needed and assembling the relevant parameters from the model results
sol	components of the results report writer that prepares the solution for outputting
solve	manage the actual call to solve the model (that is the call to invoke the optimizer)
uc	handles the user constraints
Extension	
ABS	Ancillary Balancing Services routines
ANS	ANSWER specific code
CLI	climate module routines
CMD	Windows command scripts to invoke GAMS/GDX2VEDA in order to solve and afterwards dump the model results
DEF	setting of defaults
DSC	discrete (lumpy) investment routines
ETL	endogenous technology learning routines
GMS	lower level GAMS routines to perform interpolation, apply shaping of input parameters, etc.
RUN/GEN	VEDA-FE/ANSWER specific GAMS TIMES command templates for dynamic substitution of the switches and parameters needed at run submission to identify the model variant and other options that will guide the current model run
IER	routines and extensions prepared by the University of Stuttgart (Institute for the Rational Use of Energy, IER) (e.g., for more advanced modeling of CHPs)
LIN	routines related to the alternative objective formulations
MOD	core TIMES routines preparing the actual model
MLF	code related to the MLF implementation of TIMES-MACRO
MSA	code related to the MSA implementation of decomposed TIMES-MACRO
RED	reduction algorithm routines
RPT	report writer routines
STC	code related to stochastics
STP	code related to time-stepped or partially fixed-horizon solution
TM	the core TIMES MACRO code
VDA	routines related to new TIMES features implemented under the VDA extension
VDD	directives for the VEDA-BE result analysis software

Note that these don't cover every single routine in the TIMES source code folder, but do cover most all of the core routines involved in the construction and reporting of the model. They guide the steps of the run process as follows:

- **GAMS Compile:** As mentioned above, GAMS operates as a two-phase compile then execute system. As such it first reads and assembles all the control, data, and code files into a ready executable; substituting user and/or shell provided values for all GAMS environment switches and subroutine parameter references (the %EnvVar% and %Param% references in the source code) that determine the path through the code for the requested model instance and options desired. If there are inconsistencies in input data they may result in compile-time errors (e.g., $170 for a domain definition error), causing a run to stop. See Section 2.4 for more on identifying the source of such errors.
- **Initialization:** Upon completion of the compile step, all possible GAMS sets and parameters of the TIMES model generator are declared and initialized, then established for this instance of the model from the user's data dictionary file(s) (<Case>.DD[14]). Model units are also initialized using the UNITS.DEF file, which contains the short names for the most common sets of units that are normally used in TIMES models, and which can be adjusted by the user.
- **Execution:** After the run has been prepared, the maindrv.mod routine controls all the remaining tasks of the model run. The basic steps are as follows.
    - **Pre-processing:** One major task is the pre-processing of the model input data. During pre-processing control sets defining the valid domain of parameters, equations and variables are generated (e.g., for which periods each process is available, at what timeslice level (after inheritance) is each commodity tracked and does each process operate), input parameters are inter-/extrapolated, and time-slice specific input parameters are inherited/aggregated to the correct timeslice level as required by the model generator.
    - **Preparation of coefficients:** A core activity of the model generator is the proper derivation of the actual coefficients used in the model equations. In some cases coefficients correspond directly to input data (e.g., FLO_SHAR to the flow variables), but in other cases they must be transformed. For example, the investment

[14] For simplicity, it has been assumed in this description that the name of the <case>.run/gen (for VEDA-FE/ANSWER respectively) file and the *.dd files are the same (<case_name>). The names of the two files can be different, and usually are with BASE.dd the main dataset with non-Base scenarios included in a run having <scenario>.dd/dds names (for VEDA-FE/ANSWER respectively). The listing file generated by GAMS always has the same name of the <case>.run/gen file. The name of the gdx files can be chosen by the user on the command line calling GAMS (e.g. gams mymodel.run gdx = myresults will result in a file called myresults.gdx), however, out of VEDA-FE/ANSWER the files are <case>.gdx.

cost (NCAP_COST) must be annualized, spread for the economic lifetime, and discounted before being applied to the investment variable (VAR_NCAP) in the objective function (EQ_OBJ), and based upon the technical lifetime the coefficients in the capacity transfer constraint (EQ_CPT**)** are determined to make sure that new investment are accounted for and retired appropriately.

- **Generation of model equations:** Once all the coefficients are prepared, the file eqmain.mod controls the generation of the model equations. It calls the individual GAMS routines responsible for the actual generation of the equations of this particular instance of the TIMES model. The generation of the equations is controlled by sets, parameters, and switches carefully assembled by the pre-processor to ensure that no superfluous equations or matrix intersections are generated.
- **Setting variable bounds:** The task of applying bounds to the model variables corresponding to user input parameters is handled by the bndmain.mod file. In some cases it is not appropriate to apply bounds directly to individual variables, but instead applying a bound may require the generation of an equation (e.g. the equation EQ(l)_ACTBND is created when an annual activity bound is specified for a process having a diurnal timeslice resolution).
- **Solving the model:** After construction of the actual matrix (rows, columns, intersections and bounds) the problem is passed to an optimizing solver employing the appropriate technique (LP, MIP, or NLP). The solver returns the solution of the optimization back to GAMS. The information regarding the solver status is written by TIMES in a text file called END_GAMS, which allows the user to quickly check whether the optimisation run was successful or not without having to go through the listing file. Information from this file is displayed by VEDA-FE and ANSWER at the completion of the run.
- **Reporting:** Based on the optimal solution the reporting routines calculate result parameters, e.g. annual cost information by type, year and technology or commodity. These result parameters together with the solution values of the variables and equations (both primal and dual), as well as selected input data, are assembled in the <case>.GDX file. The gdx file is then processed by the GAMS GDX2VEDA.EXE utility according to the directives contained in TIMES2VEDA.VDD control file to generate files for the result analysis software VEDA-BE[15]. The <case>.ANT file for providing results for import into ANSWER may also be produced, if desired.

2.3 Files produced during the run process

Several files are produced by the run process. These include the files produced by the shell for model initiation, the .LST listing file, which echoes the GAMS compilation and execution

[15] The basics of the TIMES2VEDA.VDD control file and the use of the result analysis software VEDA-BE are described in Part V.

process and reports on any errors encountered during solve, results files, and the QAcheck.log file. These files are summarized in Table 3 and discussed in this section.

Table 3: Files Produced by a TIMES Model Run

Extension	Produced By	Nature of the Output
ant	TIMES report writer	ANSWER model results dump
gdx	GAMS	Internal (binary) GAMS Data eXchange file with all the information associated with a model run
log	TIMES quality check routine	List of quality assurance checks (warnings and possible errors)
lst	GAMS	The basic echo of the model run, including indication of the version of TIMES being run, the compilation and execution steps, model summary statistics and error (if encountered), along with optionally an equation listing and/or solution print
vd	GDX2VEDA utility	The core model results dump of the solution including the variable/equations levels/slack and marginals, along with cost and other post-processing calculations
vde	GDX2VEDA utility	The elements of the model sets (and the definition of the attributes)
vds	GDX2VEDA utility	The set membership of the elements of the model
vdt	VEDA-FE or ANSWER	The RES topology information for the model

2.3.1 Files produced by model initiation

As discussed in Section 2.1, three sets of files are created by VEDA and ANSWER upon run initiation, the command script file VTRUN/ANSRUN.CMD, the top-level GAMS command file <Case>.RUN/GEN (for VEDA/ANSWER), and the data dictionary <scenario>.DD/DDS text file(s) that contain all the model data to be used in the run.

The VTRUN/ANSRUN.CMD script file calls GAMS, referring to the <case> file and identifying the location of the TIMES source code and gdx file. For VEDA-FE the CMD file consists of the line:

```
Call ..\<source_code_folder>\vt_gams <case>.run <source_code_folder> gamssave\<case>
```

along with a 2nd line to call the GDX2VEDA utility to process the TIMES2VEDA.VDD file to prepare the <case>.VD* result files for VEDA-BE. The ANSRUN.CMD file has a similar setup

calling ANS_GAMS.CMD in the source code folder which invokes GAMS and subsequently the GDX2VEDA utility.

The <case>.RUN/GEN file is the key file controlling the model run. It instructs the TIMES code what data to grab, what model variant to employ, how to handle the objective function, and other aspects of the model run controlled by the switches discussed in Section 3. An example .RUN file is displayed in Figure 5. Rows beginning with an asterisk (*) are comment lines for the user's convenience and are ignored by the code. Rows beginning with a dollar-sign ($) are switches that can be set by the user (usually by means of VEDA/ANSWER).

Both VEDA and ANSWER have facilities to allow the user to tailor the content of the RUN/GEN files, though somewhat differently. In VEDA-FE the Case Manager RUNFile_Tmpl button allows the basic RUN template to be brought up, and if desired carefully edited. However, the Case Manager also has a Control Panel, shown in Figure 4, where many of the more common switches can be set.

At the beginning of a <case>.RUN file the version of the TIMES code being used is identified and some option control statements that influence the information output (e.g., SOLPRINT ON/OFF to see a dump of the solution, OFF recommended) are provided. The LIMROW/LIMCOL options allow the user to turn on equation listing in the .LST file (discussed in the next section) by setting the number of rows/columns of each type to be shown.

Then compile-time dollar control options indicating which solver to use (if not the default to the particular solution algorithm), whether to echo the source code ($ON/OFFLISTING) by printing it to the LST file, and that multiple definitions of sets and parameters ($ONMULTI) are permitted (that is they can appear more than one time, which TIMES requires since first there are empty declarations for every possible parameter followed by the actual data provided by the user). Further possible dollar control options are also described in the GAMS manual.

Afterwards the content of several so-called TIMES dollar control (or environment) switches are specified. Within the source code the use of these control switches in combination with queries enables the model to skip or activate specific parts of the code. Thus it is possible to turn-on/off variants of the code, e.g. the use of the reduction algorithm, without changing the input data. The meaning and use of the different control switches is discussed in Section 3. Again these are generally set using the Case Manager/Run form in VEDA/ANSWER.

After the basic control switches, the definition of the set of all timeslices is established by means of the call to the <case>_TS.DD file before any other declarations carried out in the initialization file INITSYS.MOD. This is necessary to ensure the correct ordering of the timeslices for seasonal, weekly, or daynite storage processes. After the definition of the timeslices, the files INITSYS.COM and INITMTY.MOD, which are responsible for the declaration and initialization of all sets and parameters of the model generator, are included.

```
$TITLE  TIMES -- VERSION 4.1.0
OPTION RESLIM=50000, PROFILE=1, SOLVEOPT=REPLACE;
OPTION ITERLIM=999999, LIMROW=0, LIMCOL=0, SOLPRINT=OFF;

option LP=cplex;

*--If you want to use an optimizer other than cplex/xpress, enter it here:
*OPTION LP=MyOptimizer;

$OFFLISTING
*$ONLISTING

* activate validation to force VAR_CAP/COMPRD
$SET VALIDATE 'NO'
* reduction of equation system
$SET REDUCE   'YES'
*-------------------------------------------------------------*
* BATINCLUDE calls should all be with lower case file names!!! *
*-------------------------------------------------------------*

* initialize the environment variables
$ SET DSCAUTO YES
$   SET VDA YES
$   SET DEBUG                          'NO'
$   SET DUMPSOL                        'NO'
$   SET SOLVE_NOW                      'YES'
$   SET MODEL_NAME                     'TIMES'
$   IF DECLARED REG      $SET STARTRUN 'RESTART'
$   IF NOT DECLARED REG  $SET STARTRUN 'SCRATCH'
$SET XTQA YES
* VAR_UC being set so that non-binding constraints appear in results
$SET VAR_UC YES
 OPTION BRATIO=1;
$ SET OBJ AUTO
$ SET OBLONG YES
$SET DAMAGE NO
$ SET DSC YES
$ SET FIXBOH 2012
$ SET LPOINT B_M0000
$ SET STAGES NO
$SET SOLVEDA 'YES'
$SET VARCOST LIN

* merge declarations & data
$   ONMULTI

* the times-slices MUST come 1st to ensure ordering OK
$BATINCLUDE s_m0tthx_ts.dd
```

{continued on next page}

```
* perform fixed declarations
$SET BOTIME 1970
$BATINCLUDE initsys.mod

* declare the (system/user) empties
$   BATINCLUDE initmty.mod
*$   BATINCLUDE initmty.mod DSC
$IF NOT DECLARED REG_BNDCST $Abort "You need to use TIMES v2.3.1 or higher"

$BATINCLUDE base.dd
$BATINCLUDE b-newtechs.dd
$BATINCLUDE syssettings.dd
$BATINCLUDE base_hfcs_emi.dd
$BATINCLUDE base_delivcost.dd
$BATINCLUDE base_exim_fp.dd
$BATINCLUDE base_feedin.dd
$BATINCLUDE base_minutilall.dd
$BATINCLUDE base_ref.dd
$BATINCLUDE base_rsd-com.dd
$BATINCLUDE base_elccap.dd
$BATINCLUDE base_stock.dd
$BATINCLUDE base_heat-ex.dd
$BATINCLUDE base_hrates.dd
$BATINCLUDE flex_tfc_structure.dd
$BATINCLUDE ee_measures.dd
$BATINCLUDE re_measures.dd
$BATINCLUDE re_targets.dd
$BATINCLUDE ee_targets.dd
$BATINCLUDE co2_tax_high.dd

SET MILESTONYR /2005,2006,2007,2008,2009,2010,2011,2012,2015,2020,2025,2030,2035,2040,2045,2050/;
$SET RUN_NAME 'S_M0TTHx'

*GG* Add the LevelizedCost/Cost_NPV switches
$SET ANNCOST LEV
RPT_OPT('OBJ','1') = 1;

$ SET VEDAVDD 'YES'

* do the rest
$ BATINCLUDE maindrv.mod mod
```

Figure 5: Example of a VEDA-FE TIMES <case>.RUN file[16]

The line containing the include command for the file initmty.mod can be supplemented by calls for additional user extensions that trigger the use of additional special equations or report routines. The use of these extension options are described in more detail in Section 0.

Afterwards the data dictionary file(s) (BASE.DD, …, CO2_TAX_HIGH.DD in Figure 5) containing the user input sets and parameters are included, inserted automatically by VEDA-FE/ANSWER according to the list of scenarios in the Case Manager/Run forms by means of the $INCLUDE statements. It is normally advisable to segregate user data into "packets" as scenarios, where there may be a single Base scenario containing the core descriptions of the energy system being studied and a series of alternate scenario depicting other aspects of the system. For example, one <scenario>.DD file may contain the description of the energy system for a reference scenario, and additional <alt_scenario>.DD files (.DDS for ANSWER) may be

[16] The ANSWER GEN file will have similar content though with some syntax and perhaps slightly augmented scripts.

included containing additions or changes relative to the reference file, for example CO_2 mitigation targets for a reduction scenario, or alternative technology specifications.

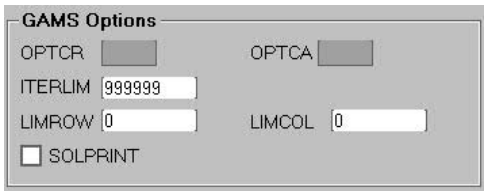
The SET MILESTONYR declaration identifies years for this model run based upon those years identified in in VEDA via the Period Defs selected on the Case Manager (and maintained in SysSettings) and the Milestone Years button on the ANSWER run form. The dollar control switch RUN_NAME contains the short name of the scenario, and is used for the name of the results files (<case>.VD*) passed to VEDA-BE.

Next in the example shown in Figure 5, some runtime switches are activated to request levelized cost reporting and splitting of investment costs into core and the incremental additional cost arising from any technology based discount rate specified in the data. See Section 3 for the full description of these and other control switches.

The last line of the <case>.RUN file invokes the file main driver routine (maindrv.mod) that initiates all the remaining tasks related to the model run (pre-processing, coefficient calculation, setting of bounds, equation generation, solution, reporting). Thus any information provided after the inclusion of the maindrv.mod file will not be considered in the main model solve request, though if the user wishes to introduce specialized post-processing of the result that could be added (or better yet handled externally by GAMS code that processes the GDX file).

2.3.2 GAMS listing file (.LST)

The GAMS listing file echoes the model run. In this file GAMS reports the compile and execution steps, presents a summary of the model statistics and objective function results, and reports any errors, if incurred. Optionally the user can request that the equation listing be turned on by specifying the LIMROW/LIMCOL (number of rows/columns of each type to be shown) and/or the solution dumped (via SOLPRINT) by means of the VEDA-FE CaseManager settings, as shown here.




```
* GEN file for use with ANSWER-TIMES GAMS code
*
* ANSWER will replace the keywords below enclosed in <> brackets.
* Replacement does not occur if line starts with *.
* Keywords are case-sensitive. Possible keywords include:
*    <Run>, <IncludeDDLines>, <TPList>, <ParameterBandParameterE>,
*    <IncludeRATRULEDDLines>, <SetModelVariantLines>,
*    <SetObjectiveFunctionLines>, <FIXBOHValue>, <TimeStep>, <Overlap>,
*    <ImportResultsIntoAnswer>, <SuppressPureZeroTSResults>
*    <SavepointLoadpointLines>, <G_DYEARValue>
*
$TITLE  NOBLE-SOFT ANSWER-TIMES VERSION 6.9.7 -- TIMES VERSION 3.9.0
OPTION LIMROW=0, LIMCOL=0, SOLPRINT=OFF, ITERLIM=50000;
OPTION RESLIM=50000, PROFILE=1, SOLVEOPT=REPLACE;
```

Figure 6: Requesting Equation Listing and Solution Print

For ANSWER these are handled by manually editing these entries in the GEN file either at runtime, or via the Run menu if the change is to be retrained as the default,

When GAMS takes its 1st pass the <Case>.LST file will report each of the individual source code modules compiled. [Note that for any particular TIMES model instance, according to the Run Switch settings, only the routines needed are invoked, as discussed in Section 3.]

A small snippet from the LST file compilation trace from an ANSWER-TIMES model run of is shown in Figure 7, where the "..." shows the nesting as one GAMS routine calls another with the appropriate parameters needed.

```
586    47887 BATINCLUDE   585      26  ....C:\AnswerTIMESv6\Gams_SrcTI\cal_red.red
587    47967 BATINCLUDE   585      38  ....C:\AnswerTIMESv6\Gams_SrcTI\cal_red.red
588    48038 BATINCLUDE   495     127  ...C:\AnswerTIMESv6\Gams_SrcTI\eqfloshr.mod
589    48064 BATINCLUDE   588      26  ....C:\AnswerTIMESv6\Gams_SrcTI\cal_red.red
590    48144 BATINCLUDE   588      38  ....C:\AnswerTIMESv6\Gams_SrcTI\cal_red.red
591    48219 BATINCLUDE   495     132  ...C:\AnswerTIMESv6\Gams_SrcTI\eqfloshr.mod
592    48245 BATINCLUDE   591      26  ....C:\AnswerTIMESv6\Gams_SrcTI\cal_red.red
593    48325 BATINCLUDE   591      38  ....C:\AnswerTIMESv6\Gams_SrcTI\cal_red.red
594    48396 BATINCLUDE   495     133  ...C:\AnswerTIMESv6\Gams_SrcTI\eqfloshr.mod
595    48422 BATINCLUDE   594      26  ....C:\AnswerTIMESv6\Gams_SrcTI\cal_red.red
596    48502 BATINCLUDE   594      38  ....C:\AnswerTIMESv6\Gams_SrcTI\cal_red.red
597    48573 BATINCLUDE   495     134  ...C:\AnswerTIMESv6\Gams_SrcTI\eqfloshr.mod
598    48599 BATINCLUDE   597      26  ....C:\AnswerTIMESv6\Gams_SrcTI\cal_red.red
599    48679 BATINCLUDE   597      38  ....C:\AnswerTIMESv6\Gams_SrcTI\cal_red.red
600    48754 BATINCLUDE   495     139  ...C:\AnswerTIMESv6\Gams_SrcTI\eqflomrk.mod
601    48782 BATINCLUDE   600      69  ....C:\AnswerTIMESv6\Gams_SrcTI\cal_red.red
602    48882 BATINCLUDE   495     140  ...C:\AnswerTIMESv6\Gams_SrcTI\eqflomrk.mod
603    48910 BATINCLUDE   602      69  ....C:\AnswerTIMESv6\Gams_SrcTI\cal_red.red
604    49010 BATINCLUDE   495     141  ...C:\AnswerTIMESv6\Gams_SrcTI\eqflomrk.mod
605    49038 BATINCLUDE   604      69  ....C:\AnswerTIMESv6\Gams_SrcTI\cal_red.red
606    49142 BATINCLUDE   495     146  ...C:\AnswerTIMESv6\Gams_SrcTI\eqire.mod
607    49199 BATINCLUDE   495     152  ...C:\AnswerTIMESv6\Gams_SrcTI\eqirebnd.mod
608    49266 BATINCLUDE   495     153  ...C:\AnswerTIMESv6\Gams_SrcTI\eqirebnd.mod
609    49333 BATINCLUDE   495     154  ...C:\AnswerTIMESv6\Gams_SrcTI\eqirebnd.mod
610    49404 BATINCLUDE   495     159  ...C:\AnswerTIMESv6\Gams_SrcTI\eqpeak.mod
611    49432 BATINCLUDE   610      28  ....C:\AnswerTIMESv6\Gams_SrcTI\cal_ire.mod
612    49476 BATINCLUDE   610      29  ....C:\AnswerTIMESv6\Gams_SrcTI\cal_ire.mod
613    49530 BATINCLUDE   610      40  ....C:\AnswerTIMESv6\Gams_SrcTI\cal_stgn.mod
614    49552 BATINCLUDE   610      43  ....C:\AnswerTIMESv6\Gams_SrcTI\cal_fflo.mod
615    49567 BATINCLUDE   614      37  .....C:\AnswerTIMESv6\Gams_SrcTI\cal_red.red
```

Figure 7: GAMS Compilation of the TIMES Source Code

If an error is encountered during the compilation operation GAMS will tag where the error occurred and report an error code. Most common in this regard is a Domain Error ($170) where perhaps there was a typo in an item name, as in the example shown in Figure 8, or the scenarios were not in the proper order and data was attempted to be assigned to a process before it was declared. Further discussion of errors encountered at this and other stages of the run process is found in Section 2.4.

```
TIMES -- VERSION 3.9.1 -- Restart (v3.9)
C o m p i l a t i o n


4392    'CCK'              'Commercial Cooking                                '
****        $170
**** LINE     38 INCLUDE     C:\AnswerTIMESv6\Gams_WrkStarter\BY-COM+STARTER.DDS
**** LINE    104 INPUT       C:\AnswerTIMESv6\Gams_WrkStarter\REF-01Z.GEN
20183  $ABORT  "*** ERRORS IN INPUT DATA/COMPILE ***"
****        $343
**** LINE     41 BATINCLUDE  C:\AnswerTIMESv6\Gams_SrcTI\err_stat.mod
                            %3  *** ERRORS IN INPUT DATA/COMPILE ***
                            %2  ABORT
                            %1  $IF NOT ERRORFREE
**** LINE     34 BATINCLUDE  C:\AnswerTIMESv6\Gams_SrcTI\maindrv.mod
                            %1  mod
**** LINE    170 INPUT       C:\AnswerTIMESv6\Gams_WrkStarter\REF-01Z.GEN

GAMS 24.4.1  r50296 Released Dec 20, 2014 WEX-WEI x86 64bit/MS Windows
03/20/16 12:22:49 Page 9
TIMES -- VERSION 3.9.1 -- Restart (v3.9)
Error Messages


170  Domain violation for element
343  Abort triggered by above statement

**** 2 ERROR(S)   0 WARNING(S)
```

Figure 8: GAMS Compilation Error

Once the data and code have been successfully complied, execution takes place, with GAMS calling each TIMES routine needed according to the switches and data for this particular run. Again the LST file echoes this execution phase, as shown in Figure 9. It is possible, though unlikely, to encounter a GAMS Execution error. The most common cause of this is the explicit specification of zero (0) as the efficiency of a process. An execution error is reported in the <Case>.LST file in a manner similar to a compilation error, tagged by “Error” at the point that the problem was encountered.

```
----  63012 Assignment FLO_CUM       0.000     0.983 SECS     49 MB       8
----  63014 Assignment FLO_CUM       0.000     0.983 SECS     49 MB       8
----  63017 Loop                     0.000     0.983 SECS     49 MB
----  63021 Assignment VAR_CUMFLO    0.000     0.983 SECS     49 MB       0
----  63022 Assignment VAR_CUMFLO    0.000     0.983 SECS     49 MB       8
----  63025 Assignment COM_CUM       0.000     0.983 SECS     49 MB       0
----  63026 Assignment COM_CUM       0.000     0.983 SECS     49 MB       0
----  63027 Assignment COM_CUM       0.000     0.983 SECS     49 MB       0
----  63029 Assignment COM_CUM       0.000     0.983 SECS     49 MB       0
----  63032 Loop                     0.000     0.983 SECS     49 MB
----  63036 Assignment VAR_CUMCOM    0.000     0.983 SECS     49 MB       0
----  63037 Assignment VAR_CUMCOM    0.000     0.983 SECS     49 MB       0
----  63041 Loop                     0.000     0.983 SECS     49 MB
----  63043 Assignment VAR_CUMCST    0.000     0.983 SECS     49 MB       0
----  63044 Assignment VAR_CUMCST    0.000     0.983 SECS     49 MB       0
----  63045 Assignment VAR_CUMCST    0.000     0.983 SECS     49 MB       0
----  63057 Assignment CNT           0.000     0.983 SECS     49 MB       1
----  63058 Assignment UC_T_EACH     0.000     0.983 SECS     49 MB    1520
----  63077 Assignment VAR_UC        0.000     0.983 SECS     49 MB       0
----  63080 Loop                     0.000     0.983 SECS     49 MB
----  63087 Assignment UC_RHS        0.000     0.983 SECS     49 MB       0
----  63108 Assignment VAR_UCR       0.000     0.983 SECS     49 MB       0
----  63112 Assignment VAR_UCR       0.000     0.983 SECS     49 MB       0
----  63113 Assignment VAR_UCR       0.000     0.983 SECS     49 MB       0
----  63114 Assignment VAR_UCR       0.000     0.983 SECS     49 MB       0
----  63118 Assignment UC_RHSR       0.000     0.983 SECS     49 MB       0
----  63139 Assignment VAR_UCT       0.000     0.983 SECS     49 MB       0
----  63142 Loop                     0.000     0.983 SECS     49 MB
----  63149 Assignment UC_RHST       0.000     0.983 SECS     49 MB       0
----  63170 Assignment VAR_UCRT      0.000     0.983 SECS     49 MB       0
```

Figure 9: GAMS Execution of the TIMES Source Code

Once execution of the matrix generator has completed GAMS reports the model run statistics (Figure 10), and automatically invokes the solver.

```
GAMS 24.4.1  r50296 Released Dec 20, 2014 WEX-WEI x86 64bit/MS Windows
05/13/15 13:44:59 Page 11
TIMES -- VERSION 3.6.0 -- Restart (v3.6)
Model Statistics    SOLVE TIMES Using MIP From line 63932


MODEL STATISTICS

BLOCKS OF EQUATIONS          93     SINGLE EQUATIONS      109,278
BLOCKS OF VARIABLES          13     SINGLE VARIABLES       58,035  4 projected
NON ZERO ELEMENTS       419,203


----  63932 Solve Fini TIMES         0.109     2.527 SECS     86 MB  419203
GENERATION TIME      =        1.544 SECONDS     86 MB  24.4.1 r50296 WEX-WEI


EXECUTION TIME       =        2.527 SECONDS     86 MB  24.4.1 r50296 WEX-WEI
----  63932 GAMS Fini                0.047     0.047 SECS     86 MB
----      1 ExecInit                 0.000     0.000 SECS     46 MB
----  63932 Solve Alg  TIMES         0.000     0.000 SECS     46 MB
```

Figure 10: CPLEX Solver Statistics

If the OPTION LIMROW/LIMCOL is set to non-0 the equation mathematics are displayed in the list file, by equation block and/or column intersection, as shown in Figure 11 and Figure 12 respectively.

```
---- EQG_COMBAL  =G=  Commodity Balance (=G=)

EQG_COMBAL(STARTER,2013,ELCD,FAD)..  VAR_ACT(STARTER,2013,2013,GRD-ELCD-1,FAD) - VAR_ACT(STARTER,2013,2013,XAGRELC00,FAD) - VAR_ACT
(STARTER,2013,2013,XCOMELC00,FAD) - VAR_ACT(STARTER,2013,2013,XRSDELC00,FAD) - VAR_ACT(STARTER,2013,2013,XINDELC00,FAD)

     - VAR_ACT(STARTER,2013,2013,XTRNELC00,FAD) + VAR_ACT(STARTER,2013,2013,ZZBCKELC,FAD) =G= 0 ; (LHS = 0)

EQG_COMBAL(STARTER,2013,ELCD,FAN)..  VAR_ACT(STARTER,2013,2013,GRD-ELCD-1,FAN) - VAR_ACT(STARTER,2013,2013,XAGRELC00,FAN) - VAR_ACT
(STARTER,2013,2013,XCOMELC00,FAN) - VAR_ACT(STARTER,2013,2013,XRSDELC00,FAN) - VAR_ACT(STARTER,2013,2013,XINDELC00,FAN)

     - VAR_ACT(STARTER,2013,2013,XTRNELC00,FAN) + VAR_ACT(STARTER,2013,2013,ZZBCKELC,FAN) =G= 0 ; (LHS = 0)

EQG_COMBAL(STARTER,2013,ELCD,FAP)..  VAR_ACT(STARTER,2013,2013,GRD-ELCD-1,FAP) - VAR_ACT(STARTER,2013,2013,XAGRELC00,FAP) - VAR_ACT
(STARTER,2013,2013,XCOMELC00,FAP) - VAR_ACT(STARTER,2013,2013,XRSDELC00,FAP) - VAR_ACT(STARTER,2013,2013,XINDELC00,FAP)

     - VAR_ACT(STARTER,2013,2013,XTRNELC00,FAP) + VAR_ACT(STARTER,2013,2013,ZZBCKELC,FAP) =G= 0 ; (LHS = 0)

EQG_COMBAL(STARTER,2013,ELCD,SPD)..  VAR_ACT(STARTER,2013,2013,GRD-ELCD-1,SPD) - VAR_ACT(STARTER,2013,2013,XAGRELC00,SPD) - VAR_ACT
(STARTER,2013,2013,XCOMELC00,SPD) - VAR_ACT(STARTER,2013,2013,XRSDELC00,SPD) - VAR_ACT(STARTER,2013,2013,XINDELC00,SPD)

     - VAR_ACT(STARTER,2013,2013,XTRNELC00,SPD) + VAR_ACT(STARTER,2013,2013,ZZBCKELC,SPD) =G= 0 ; (LHS = 0)

EQG_COMBAL(STARTER,2013,ELCD,SPN)..  VAR_ACT(STARTER,2013,2013,GRD-ELCD-1,SPN) - VAR_ACT(STARTER,2013,2013,XAGRELC00,SPN) - VAR_ACT
(STARTER,2013,2013,XCOMELC00,SPN) - VAR_ACT(STARTER,2013,2013,XRSDELC00,SPN) - VAR_ACT(STARTER,2013,2013,XINDELC00,SPN)

     - VAR_ACT(STARTER,2013,2013,XTRNELC00,SPN) + VAR_ACT(STARTER,2013,2013,ZZBCKELC,SPN) =G= 0 ; (LHS = 0)
```

Figure 11: Equation Listing Example

```
VAR_ACT(STARTER,2015,2015,EEBIOGAS-ST-X0,WIP)
                (.LO, .L, .UP, .M = 0, 0, +INF, 0)
        0.2859  EQ_OBJVAR(STARTER,CUR)
        1       EQG_ACTBND(STARTER,2015,EEBIOGAS-ST-X0,ANNUAL)
        1       EQL_CAPACT(STARTER,2015,2015,EEBIOGAS-ST-X0,WIP)
        1       EQG_COMBAL(STARTER,2015,ELCT,WIP)
       -4       EQG_COMBAL(STARTER,2015,PWRBIOGAS,ANNUAL)

VAR_ACT(STARTER,2015,2015,EEBIOMSW-ST-X0,FAD)
                (.LO, .L, .UP, .M = 0, 0, +INF, 0)
        0.2859  EQ_OBJVAR(STARTER,CUR)
        1       EQG_ACTBND(STARTER,2015,EEBIOMSW-ST-X0,ANNUAL)
        1       EQL_CAPACT(STARTER,2015,2015,EEBIOMSW-ST-X0,FAD)
        1       EQG_COMBAL(STARTER,2015,ELCT,FAD)
       -5.56    EQG_COMBAL(STARTER,2015,PWRBIOMSW,ANNUAL)

VAR_ACT(STARTER,2015,2015,EEBIOMSW-ST-X0,FAN)
                (.LO, .L, .UP, .M = 0, 0, +INF, 0)
        0.2859  EQ_OBJVAR(STARTER,CUR)
        1       EQG_ACTBND(STARTER,2015,EEBIOMSW-ST-X0,ANNUAL)
        1       EQL_CAPACT(STARTER,2015,2015,EEBIOMSW-ST-X0,FAN)
        1       EQG_COMBAL(STARTER,2015,ELCT,FAN)
       -5.56    EQG_COMBAL(STARTER,2015,PWRBIOMSW,ANNUAL)

VAR_ACT(STARTER,2015,2015,EEBIOMSW-ST-X0,FAP)
                (.LO, .L, .UP, .M = 0, 0, +INF, 0)
        0.2859  EQ_OBJVAR(STARTER,CUR)
        1       EQG_ACTBND(STARTER,2015,EEBIOMSW-ST-X0,ANNUAL)
        1       EQL_CAPACT(STARTER,2015,2015,EEBIOMSW-ST-X0,FAP)
        1       EQG_COMBAL(STARTER,2015,ELCT,FAP)
       -5.56    EQG_COMBAL(STARTER,2015,PWRBIOMSW,ANNUAL)
```

Figure 12: Variable Listing Example

And if the SOLPRINT=ON option is activated then the level and marginals are reported as shown in Figure 13.

```
---- EQU EQL_FLOMRK  Process market-share (=L=)

                                          LOWER          LEVEL          UPPER         MARGINAL

STARTER.2015.CHB-F-COA-UP    .CHB.ANNUAL  -INF           -4.7599          .              .
STARTER.2015.CHB-F-GEO-UP    .CHB.ANNUAL  -INF           -0.5895          .              .
STARTER.2015.CHB-F-LTH-UP    .CHB.ANNUAL  -INF              .             .            -0.2796
STARTER.2015.RHB-F-BIOPSF-UP.RHB.ANNUAL   -INF           -0.6310          .              .
STARTER.2015.RHB-F-COALIG-UP.RHB.ANNUAL   -INF              .             .            -0.0070
STARTER.2015.RHB-F-LTH-UP    .RHB.ANNUAL  -INF           -1.7232          .              .
STARTER.2015.RHB-Q-AD-UP     .RHB.ANNUAL  -INF          -37.9473          .              .
STARTER.2015.RHB-Q-BE-UP     .RHB.ANNUAL  -INF              .             .            -0.0906
STARTER.2015.RHB-Q-IM-UP     .RHB.ANNUAL  -INF              .             .            -0.0739
STARTER.2015.TBU-F-GASNAT-UP.TBU.ANNUAL   -INF           -0.0287          .              .
STARTER.2015.THS-F-GASNAT-UP.THS.ANNUAL   -INF           -0.0385          .              .
STARTER.2015.TLD-S-CP-UP     .TLD.ANNUAL  -INF              .             .          -193.7121
STARTER.2015.TLD-S-FS-UP     .TLD.ANNUAL  -INF              .             .          -177.4296
STARTER.2015.TLD-S-LS-UP     .TLD.ANNUAL  -INF           -0.3822          .              .
STARTER.2015.TLD-S-MC-UP     .TLD.ANNUAL  -INF              .             .            -2.9796
STARTER.2015.TLD-S-MV-UP     .TLD.ANNUAL  -INF              .             .           -75.3503
STARTER.2015.TLD-S-PU-UP     .TLD.ANNUAL  -INF              .             .           -66.5300
STARTER.2015.TLD-S-SS-UP     .TLD.ANNUAL  -INF              .             .          -146.9064
STARTER.2015.TLD-T-FX-UP     .TLD.ANNUAL  -INF              .             .            -1.0684
STARTER.2015.TLD-T-HY-UP     .TLD.ANNUAL  -INF              .             .           -18.6543
STARTER.2015.TLD-T-PH-UP     .TLD.ANNUAL  -INF              .             .           -15.3928
STARTER.2015.TMD-F-GASNAT-UP.TMD.ANNUAL   -INF           -0.0498          .              .
STARTER.2020.CHB-F-COA-UP    .CHB.ANNUAL  -INF           -5.2941          .              .
```

Figure 13: Solution Dump Example

Upon successful solving the model the solution statistics are reported (Figure 14), where in this case CPLEX was used to solve a MIP model variant (in this example), and the report writer invoked to finish up by preparing the report. If the solver is not able to find an optimal solution, a non-Normal solve status will be reported, and the user can search the LST file for the string "INFES" for an indication of which equations are preventing model solution. Again, further information on the possible causes and resolution of such errors is found in Section 2.4.

```
Solution Report     SOLVE TIMES Using MIP From line 63932


               S O L V E      S U M M A R Y

     MODEL   TIMES                OBJECTIVE  OBJZ
     TYPE    MIP                  DIRECTION  MINIMIZE
     SOLVER  CPLEX                FROM LINE  63932

**** SOLVER STATUS     1 Normal Completion
**** MODEL STATUS      1 Optimal
**** OBJECTIVE VALUE           6543356.6761

 RESOURCE USAGE, LIMIT        240.226     50000.000
 ITERATION COUNT, LIMIT      1202         50000

**** Reading with SOLVEOPT=REPLACE (0) ****

IBM ILOG CPLEX   24.4.1 r50296 Released Dec 20, 2014 WEI x86 64bit/MS Windows
--- GAMS/Cplex licensed for continuous and discrete problems.
Cplex 12.6.1.0
```

Figure 14: Solver Solution Summary

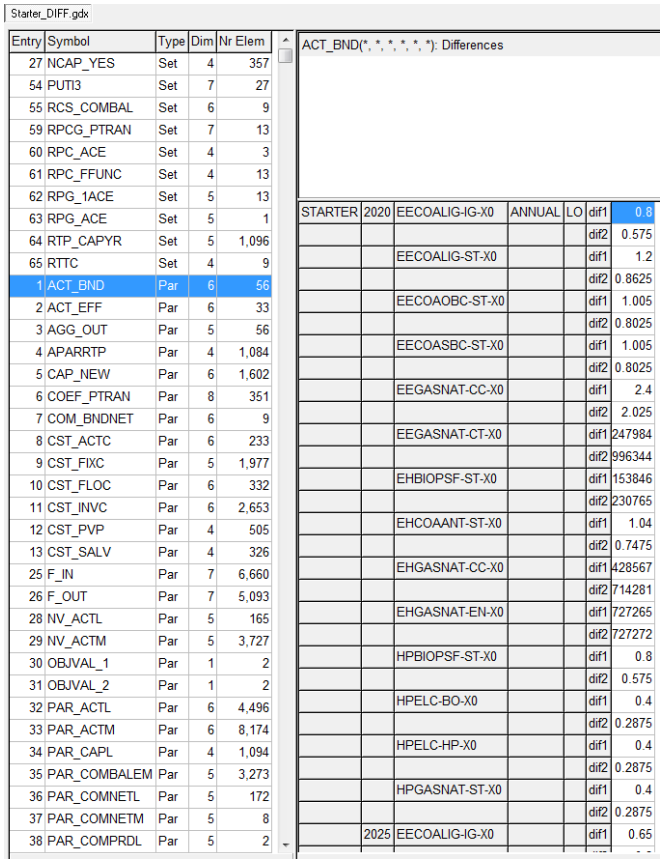
The actual production of the dump of the model results is performed by the report writer for ANSWER resulting in a <Case>.ANT file which is imported back into ANSWER after the run complete and/or the GDX2VEDA utility prepared by GAMS and DecisionWare to facilitate the exchange of information from GAMS to VEDA-BE, which may be used with both VEDA-FE and ANSWER.

2.3.3 Results files

The TIMES report writing routine produces two sets of results-related outputs (along with the quality control LOG discussed in the next section). The <case>.ANT file is an ASCII text file, with results ready for import into ANSWER. The GAMS Data eXchange file (GDX) contains all the information associated with a model run [input data, intermediate parameters, model results (primal and dual)] in binary form. The GDX file may be examined by means of the GAMSIDE, available from the Windows Start Menu in the GAMS folder (or as a shortcut from the desktop if put there), if one really wants to dig into what's happening inside of a TIMES run (that is, the set members, preprocessor calculations, the model solution and the reporting parameters calculated).

A more powerful feature within the GAMSIDE is a GDXDIFF facility under Utilities. As seen in Figure 15, the utility shows the differences between all components, comparing two model runs. Within the GDXDIFF utility, the user identifies the GDX files from the two runs and

requests the resulting comparison GDX be prepared. The display then shows any differences between the two runs. The GDXDIFF is most effectively used by instructing VEDA to Create DD for the two runs via the Options and Case Manager forms, as shown in Figure 16. Once the comparison GDX has been created, it is viewed in the GAMSIDE. By sorting by Type and scanning down one Symbol at a time, one can determine exactly what input data being sent to GAMS for the two runs is different.



Entry	Symbol	Type	Dim	Nr Elem
27	NCAP_YES	Set	4	357
54	PUTI3	Set	7	27
55	RCS_COMBAL	Set	6	9
59	RPCG_PTRAN	Set	7	13
60	RPC_ACE	Set	4	3
61	RPC_FFUNC	Set	4	13
62	RPG_1ACE	Set	5	13
63	RPG_ACE	Set	5	1
64	RTP_CAPYR	Set	5	1,096
65	RTTC	Set	4	9
1	ACT_BND	Par	6	56
2	ACT_EFF	Par	6	33
3	AGG_OUT	Par	5	56
4	APARRTP	Par	4	1,084
5	CAP_NEW	Par	6	1,602
6	COEF_PTRAN	Par	8	351
7	COM_BNDNET	Par	6	9
8	CST_ACTC	Par	6	233
9	CST_FIXC	Par	5	1,977
10	CST_FLOC	Par	6	332
11	CST_INVC	Par	6	2,653
12	CST_PVP	Par	4	505
13	CST_SALV	Par	4	326
25	F_IN	Par	7	6,660
26	F_OUT	Par	7	5,093
28	NV_ACTL	Par	5	165
29	NV_ACTM	Par	5	3,727
30	OBJVAL_1	Par	1	2
31	OBJVAL_2	Par	1	2
32	PAR_ACTL	Par	6	4,496
33	PAR_ACTM	Par	6	8,174
34	PAR_CAPL	Par	4	1,094
35	PAR_COMBALEM	Par	5	3,273
36	PAR_COMNETL	Par	5	172
37	PAR_COMNETM	Par	5	8
38	PAR_COMPRDL	Par	5	2

STARTER	2020	EECOALIG-IG-X0	ANNUAL	LO	dif1	0.8
					dif2	0.575
		EECOALIG-ST-X0			dif1	1.2
					dif2	0.8625
		EECOAOBC-ST-X0			dif1	1.005
					dif2	0.8025
		EECOASBC-ST-X0			dif1	1.005
					dif2	0.8025
		EEGASNAT-CC-X0			dif1	2.4
					dif2	2.025
		EEGASNAT-CT-X0			dif1	247984
					dif2	996344
		EHBIOPSF-ST-X0			dif1	153846
					dif2	230765
		EHCOAANT-ST-X0			dif1	1.04
					dif2	0.7475
		EHGASNAT-CC-X0			dif1	428567
					dif2	714281
		EHGASNAT-EN-X0			dif1	727265
					dif2	727272
		HPBIOPSF-ST-X0			dif1	0.8
					dif2	0.575
		HPELC-BO-X0			dif1	0.4
					dif2	0.2875
		HPELC-HP-X0			dif1	0.4
					dif2	0.2875
		HPGASNAT-ST-X0			dif1	0.4
					dif2	0.2875
	2025	EECOALIG-IG-X0			dif1	0.65

Figure 15: GAMSIDE View of the GDXDIFF Run Comparison

However, the most common use of the GDX is its further processing to generate files for the result analysis software VEDA-BE[17]. ETSAP worked with GAMS a number of years ago to develop a standalone utility (GDX2VEDA) to process the GAMS GDX file and produce the files read into VEDA-BE. The GDX2VEDA utility process a directives file (TIMES2VEDA.VDD) to determine which sets and model results are to be included and prepare said information for VEDA-BE. A general default version of the VDD is distributed with TIMES in the source code folder (for core TIMES, Stochastics, and MACRO), but may be augmented by the user if other information is desired from the solution. However, the process of changing the VDD should be done in consultation with someone fully familiar with the GAMS GDX file for TIMES and the

[17] The basics of the TIMES2VEDA.VDD control file and the use of the result analysis software VEDA-BE are described in Part V.

basics of the GDX2VEDA utility. See Part V, Appendix B, for further information on the GDX2VEDA utility and VDD directives file.

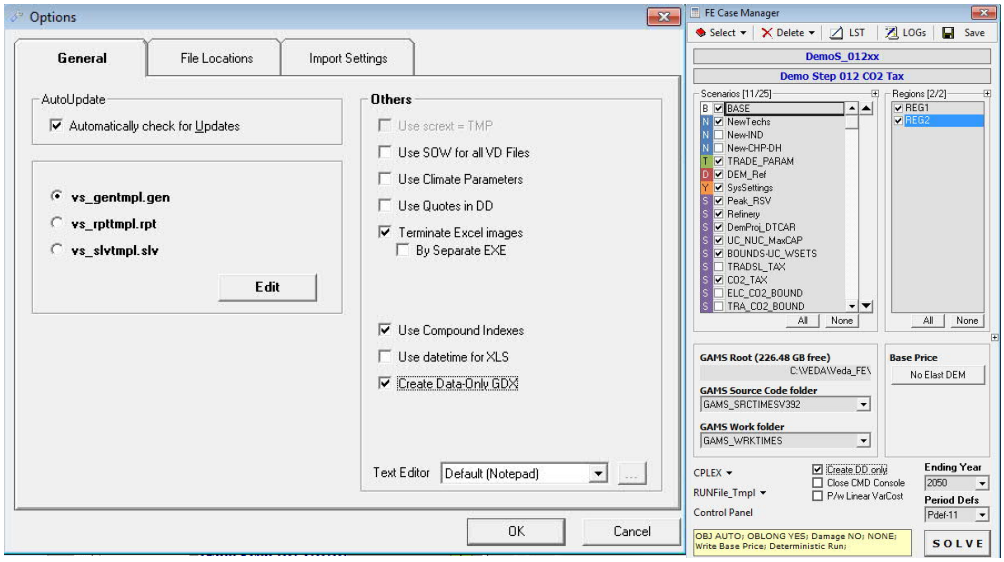


Figure 16: VEDA Setup for Data Only GDX Request

The call to the GDX2VEDA routine is embedded in the VTRUN/ANSRUN.CMD command routines. There are three files produced for VEDA-BE by the GDX2VEDA utility: the <Case>.VD data dump with the attributes, and associated VDE (set elements), VDS (sets definition). In addition, VEDA-FE and ANSWER produce a <Case>.VDT (topology) file with the RES connectivity information. These files never require user intervention, though users wishing to post-process the GDX2VEDA results with their own tailored software, rather than VEDA-BE, might choose to parse the VD* files to extract the desired information.

Note that for both ANSWER and VEDA-BE, for the most part low-level (that is commodity/process) results are reported, along with some aggregate cost numbers (such as regional and overall objective function). It is left up to the user to construct relevant sets and tables in VEDA-BE to organize and aggregate the results into meaningful tables. Refer to Part V for a discussion of how to go about assembling report tables in VEDA-BE. For ANSWER the user is left with only the raw results and thereby needs to come up with their own approach to producing useful usable reporting tables, or use VEDA-BE.

In addition, as discussed in Section 3.10, there are a number of switches that control the report writer itself in terms of how it calculates certain outputs and prepares the results as part of the post-processing. Collectively these mechanisms provide the user with a wide range of reporting results and tools for dissecting and assembling the modeling results as part of effectively using TIMES to conduct energy policy analyses.

2.3.4 QA check report (LOG)

In order to assist the user with identifying accidental modelling errors, a number of sanity checks are done by the model generator. If incorrect or suspicious specifications are found in these checks, a message is written in a text file named QA_CHECK.LOG, in the working folder. The checks implemented in TIMES Version 3.9.3 are listed in Table 5. The "Log entry" column shows the identification given for each suspicious specification.

Table 4: TIMES Quality Assurance Checks (as of Version 4.4.0)

Type[18]	Message / Description	Severity	Log entry
STD	User-provided G_YRFR values are not valid year fractions: The sum of year fractions over timeslices does not sum up correctly. The fractions are normalized so that they sum up to 1 over the full year.	warning	region, ts-level, timeslice
STD	Delayed Process but PAST Investment: Process availability has been delayed by using PRC_NOFF or NCAP_START, but also has existing capacity.	warning	region, process
STD	Commodities/processes defined at non-existing TSLVL: PRC_TSL or COM_TSL has been specified on a timeslice level not used in the model.	severe error	number of COM/PRC reset to ANNUAL
STD	NCAP_TLIFE out of feasible range: NCAP_TLIFE specified has a value of either less than 0.5 or greater than 200. Values less than 0.5 are reset to 1.	warning	region, process, vintage
STD	Inconsistent CAP_BND(UP/FX) defined for process capacity: CAP_BND(UP/FX) value specified has a value lower than the residual capacity remaining available in the period, and retirements are disabled.	warning	region, process, period
STD	Flow OFF TS level below variable TS level: A PRC_FOFF attribute with a timeslice below the flow level has been specified; the OFF specification is ignored.	warning	region, process, commodity, timeslice
STD	COM_FR does not sum to unity (T=first year): The sum of COM_FR over all timeslices at the COM_TSL level is not equal to 1, and is therefore normalized to 1.	warning	region, commodity, milestone
STD	Unsupported diverging trade topology: The model generator detects an unsupported complex topology of an IRE process, which cannot be properly handled	error	region, process
STD	FLO_EMIS with no members of source group in process: A FLO_EMIS with a source group that has no members for the process has been specified. The parameter is ignored.	severe error	region, process, group, commodity
STD	Unsupported FLO_SHAR: C not in RPC or CG: The commodity in FLO_SHAR is either not in the process topology or not a member of the group specified	error	region, process, commodity,

[18] STD=standard QA check (always done), XTD=extended QA check (activate with XTQA)

Type[18]	Message / Description	Severity	Log entry
			group
STD	FLO_SHAR conflict: Both FX + LO/UP specified, latter ignored: Too many FLO_SHAR bounds are specified, if both FX and LO/UP are specified at the same time.	warning	region, process, vintage, commodity, group
STD	Inconsistent sum of fixed FLO_SHARs in Group: All flows in a group have a fixed share, but the sum of the fixed FLO_SHAR values is not equal to 1.	warning	region, process, vintage, group
STD	Defective sum of FX and UP FLO_SHARs in Group: All flows in a group have either a fixed or an upper share, but the sum of the FLO_SHAR values is less than 1.	warning	region, process, vintage, group
STD	Excessive sum of FX and LO FLO_SHARs in Group: All flows in a group have either a fixed or a lower share, but the sum of the FLO_SHAR values is greater than 1.	warning	region, process, vintage, group
STD	NCAP_AF/ACT_BND Bounds conflict: Value at PRC_TS level and below, latter ignored	warning	region, process, vintage, timeslice
STD	NCAP_AF Bounds conflict: FX + LO/UP at same TS-level, latter ignored	warning	region, process, vintage, timeslice
STD	FLO_SHAR/FLO_FR Bounds conflict: Value at RPCS_VAR level and below, latter ignored	warning	region, process, vintage, timeslice
STD	FLO_SHAR Bounds conflict: FX + LO/UP at same TS-level, latter ignored	warning	region, process, vintage, commodity, group
STD	COM_BNDNET/COM_BNDPRD/IRE_BND Bounds conflict: Value at COM_TS level and below, latter ignored	warning	region, milestone, commodity, timeslice
STD	IRE_FLO import commodity not in TOP_IRE: An invalid IRE_FLO with the imported commodity not in the process topology has been specified	error	region, process, commodity
STD	CHP process with zero CEH but only upper bound on CHPR: A CHP process has only an upper bound on NCAP_CHPR, but a zero or missing NCAP_CEH, which indicates a modelling error	error	region, process

Type[18]	Message / Description	Severity	Log entry
STD	Year Fraction G_YRFR is ZERO! A timeslice with G_YRFR is within the timeslice tree. This should actually never happen, because TIMES automatically removes timeslices with a zero year fraction from the active timeslices.	fatal	region, timeslice
STD	Illegal system commodity in topology: ACT / ACTGRP is a reserved name which should never be used as a commodity in the model topology.	fatal	region, process
STD	Commodity in CG of process P but not in topology: A commodity group assigned to a process contains members not in the process topology (or no members in the process topology).	severe error	region, process, comm.group
STD	Elastic Demand but either COM_BPRICE/ELAST/VOC missing: Either a demand that has COM_ELAST or COM_STEP defined but does not have COM_BPRICE, COM_ELAST, or COM_VOC, defined.	warning	region, commodity, LO/UP
STD	Commodity type is also a commodity: Commodity types are reserved names that cannot be used as commodity names.	fatal	region, commodity type
STD	Commodity has ambiguous base type: The base type for some commodity is not uniquely defined. All commodities should have a unique base type defined (NRG/MAT/DEM/ENV/FIN).	severe error	region, commodity
STD	Demand: DEM commodity with missing COM_PROJ Projection: A demand commodity without any demand projection is found.	warning	region, commodity
STD	Demand: COM_PROJ specified for non-DEM commodity: Demand is projected for a non-demand commodity.	warning	region, commodity
STD	Phantom entries found in topology (process/commodity not in SET PRC/COM): This error is usually triggered when a GAMS domain violation has occurred, which may cause unexpected behaviour of the GAMS code.	fatal	region, process, commodity
STD	Process with missing or mismatched CG/PRC_ACTUNIT: Process with missing or several PRC_ACTUNT entries.	fatal	region, process
STD	Illegal dependency of substituted auxiliary commodities C1 and C2 in FLO_SUM: This error should not occur, because the GAMS code should make sure that C1 and C2 are not both substituted. If this error is issued, contact TIMES maintenance.	fatal	region, process, commodity1, commodity2
STD	NCAP_AFX defined for NON-vintaged dispatchable process with ACT_MINLD: Shaping of NCAP_AF is not supported for non-vintaged processes having ACT_MINLD defined.	warning	region, process
STD	Active currency but not member of set CUR: Currency referred to in some attributes is not defined in the set CUR.	fatal	currency
STD	Internal Region without Discount Rate: TIMES requires a discount rate defined for all internal regions.	fatal	region
STD	Active Currency without Discount Rate: A currency is being used without discount rate, or conversion to another currency that has a discount rate.	fatal	region, currency

Type[18]	Message / Description	Severity	Log entry
STD	Process with zero PRC_ACTFLO for C in PG: A zero PRC_ACTFLO has been specified for a commodity in the primary group.	fatal	region, process, commodity
XTD	Same Commodity IN and OUT of non-STG process: A process has been defined to have the same commodity as an input and an output, and it is not a storage process; that is not supported.	severe error	region, process, commodity
XTD	IRE Process with invalid Parameters: Some FLO_FUNC, FLO_SUM, FLO_SHAR or UC_FLO parameter not supported for IRE processes has been specified.	error	region, process, com-group
XTD	Invalid Commodity / Group used in ACT_EFF - parameter ignored: An invalid ACT_EFF attribute with a CG not containing members on the shadow side or in the PG has been specified.	error	region, process, group
XTD	FLO_SUM Commodity Not in RPC - parameter ignored: An invalid FLO_SUM has been defined where the commodity is not in the process topology.	error	region, process, group, commodity
XTD	FLO_SUM Commodity Not in CG1 - parameter ignored: An invalid FLO_SUM has been defined where the commodity is not a member of the first group, CG1.	error	region, process, group, commodity
XTD	PTRANS between CG1 and CG2 in both directions: A FLO_FUNC or FLO_SUM between groups CG1 and CG2 has been specified in both directions.	severe error	region, process, group1, group2
XTD	RPC in TOP not found in any ACTFLO / FLO_SHAR / FLO_FUNC / FLO_SUM: Some commodity in the topology does not seem to be tied to anything, at least by means of any of the most common attributes; the user is advised to check that this is not a modelling error.	warning	region, process, commodity, IN/OUT
XTD	Empty Group in FLO_SUM/FLO_FUNC/FLO_SHAR: A group that has no members in the process topology has been used for a process attribute. Detects also an empty primary group.	severe error	region, process, group
XTD	Both NCAP_AF and NCAP_AFA specified for same process: Specifying both NCAP_AF(bd) and NCAP_AFA(bd) for an ANNUAL level process is ambiguous and should be avoided.	warning	region, process, vintage
XTD	Too Long Commodity Lead Time: A value of NCAP_CLED > NCAP_ILED has been specified	warning	region, process, commodity
XTD	CHP parameter specified for Non-CHP process: An NCAP_BPME, NCAP_CHPR or NCAP_CEH parameter has been specified for a process that is not defined to be CHP.	error	region, process, vintage
XTD	PG of CHP process consists of single commodity yet has a CHP-ratio: A CHP process has a NCAP_CHPR specified but has only a single commodity in the primary group.	warning	region, process

Type[18]	Message / Description	Severity	Log entry
XTD	Found CHP processes without CHP-ratio defined: A CHP process has no NCAP_CHPR defined	warning	number of such processes
XTD	Found CHP processes with PG commodity efficiencies - unsupported: Specifying ACT_EFF on some flow(s) in the PG is not supported for CHP processes, and may lead to unexpected results.	warning	region, process
XTD	Found CHP processes without electricity in the PG: A CHP process is found with no electricity commodity in the PG.	warning	region, process

2.4 Errors and their resolution

Errors may be encountered during the compilation, execution (rarely), or solve stages of a TIMES model run. During the compilation step, if GAMS encounters any improperly defined item the run will be halted with a Domain or similar error and the user will need to examine the TIMES quality control LOG or GAMS listing (LST) files to ascertain the cause of the problem. While such problems are not normally encountered, some that might occur include:

- an item name was mistyped and therefore not defined;
- an item was previously defined in one scenario but defined differently in another;
- an item was not properly declared for a particular parameters (e.g., a non-trade process using an IRE parameter), and
- scenarios were specified for the run in the wrong order so a data reference is encountered before the declaration (e.g., a bound on a new technology option is provided before it has been identified).

During the execution phase, if GAMS encounters any runtime errors it will halt and report where the error occurred in the LST file. While such problems are not normally encountered some causes of an execution error might be:

- an explicit 0 is provided for an efficiency resulting in a divide by 0, and
- there is a conflict between a lower and upper bound.

Most commonly errors are encountered during the solve process, resulting in an infeasibility. Some causes of the model not being able to solve might be:

- due to bounds, the energy system cannot be configured in such a way as to meet the limit;
- owing to mis-specifying the demand serviced by a device, there is no or not enough capacity to satisfy said demand, and
- the RES is not properly connected so a needed commodity is not able to reach the processes needing it.

To identify the cause of a solve error, if using CPLEX the user can activate the Infeasibility Finder (set in the CPLEX.OPT as default (via the IIS command) in VEDA-FE Case Manager or said file distributed with ANSWER). The CPLEX Infeasibility Finder will identify the explicit row/columns corresponding to the first infeasibility encountered and list the conflict involved in

the <Case>.LST file, such as shown here where the electricity balance equation can't be satisfied (due to a limit being imposed on the first year electric grid capacity that is too small).

```
Implied bounds make row 'EQG_COMBAL('STARTER'.2013.'ELCD'.'FAD')' infeasible.
```

This helps with tracking down the culprit, but the user still needs to figure out why the problem occurred. When using a solver other than CPLEX, or if the Infeasibility Finder is not activated, then the solution dump will be tagged for all the potentially interrelated model variables/equations that were not in equilibrium at the time the solve stopped. The user can find these by searching the LST file for the string "INFES".

As a last resort, the model can be run with the equation listing turned on by setting LIMROW/LIMCOL to, say, 1000 in the <case>.RUN (via the Case Manager) / GEN (via Edit the GEN from the Run form) file, although the equations in this form can be challenging to interpret.

3 Switches to control the execution of the TIMES code

This Section describes the various GAMS control variables available in TIMES as control switches that can be set by the user in the model <case>.RUN/GEN file for VEDA-FE/ANSWER respectively. As discussed in Section 2, VEDA-FE and ANSWER, in most cases automatically take care of inserting the proper switches into the run file, so the user normally does not have to modify the run file at all. The switches are set in the highly user-friendly GUI interface of the user shell, which uses a run file template and inserts all run-specific switches correctly into the run file of each model run. These are managed by the user via the CaseManager (Control Panel) and Run/Edit GEN Template parts of VEDA-FE and ANSWER respectively.

In the sub-sections that follow, unless otherwise stated, the basic syntax for the inclusion of control switch options in the main <case>.RUN/GEN GAMS directive file is $SET <option> <value>. The various options are grouped according to the nature of their usage by sub-section.

3.1 Run name case identification

The use of the RUN_NAME control variable is practically mandatory when running TIMES. By setting the RUN_NAME control variable, the user gives a name to the model run, which will be used when generating various output files and/or loading information from a previously generated file that has the same name. The control variable is used in the following way:

```
$SET RUN_NAME runname
```

Here the ***runname*** identifier (corresponding to the run <case> name) is a string of letters, numbers and other characters (excluding spaces), such that the name complies with the rules for the base name of files. It will be used to construct names for the various files comprising a model run, as listed in Table 5.

Table 5: RUN_NAME TIMES Files

Extension*	Description
ANT	ANSWER results dump
GDX	GAMS data exchange file (for GAMS2VEDA processing)
*_DP.GDX	Base demand prices to seed a TIMES elastic demand policy run
LOG	Optional GAMS file producing a trace of the model resource usage (activated by lo=1 on the GAMS call line in ANS_GAMS / VT_GAMS.CMD, which needs to be added by the user manually if needed)
LST	GAMS output file with the compile/execute/solve trace, and optional solution dump (via SOLPRINT=YES on the OPTIONS line at the top of the RUN command script)
*_P.GDX	Save/Load point GAMS restart files
RUN	Top level routine calling GAMS (and for VEDA-FE the GDX2VEDA routine)
*_RunSummary.log	Run summary for the associated model run
*_TS.DD	Timeslices declaration for the associated model run
VD*	Suite of results/Set definition(S)/Element description(E)/topology(T) for VEDA-BE

3.2 Controls affecting equilibrium mode

TIMES has a number of variants or model instances embedded in the within the full set of GAMS source code files. Which path through the code is taken is determined mainly the activation (or not) of various control switches, as summarized in this section.

3.2.1 Endogenous elastic demands [TIMESED]

The TIMESED control variable is one of the most important TIMES control variables. It has to be used whenever the full partial equilibrium features of TIMES (that is, employing elastic demands) are to be utilized. For running a baseline scenario to be subsequently used as the reference scenario for partial equilibrium analyses with elastic demands, the following setting should be used:

```
$SET TIMESED NO
```

This setting indicates that the user plans to use the resulting price levels from the current run as reference prices in subsequent runs with elastic demands. The setting causes the model generator to create the following (identical) two files from the Baseline run (the second file is a backup copy):

- `Com_Bprice.gdx`
- `%RUN_NAME%_DP.gdx`

For running any policy scenarios with elastic demands, using price levels from a previous run as reference prices, one must use the following setting:

```
$SET TIMESED YES
```

The reference price levels are read from a file named 'Com_Bprice.gdx', which is expected to reside in the current directory folder where the model run takes place. Therefore, the Baseline scenario using the setting $SET TIMESED NO has to be run before running the policy scenarios, or the correct 'Com_Bprice.gdx' be otherwise restored from some backup copy.

The VEDA-FE CaseManager(BasePrice) and ANSWER Run(ModelVariant) buttons allow the user to easily control setting of the TIMESED switch and thereby creating/including the Com_Bprice.GDX as appropriate. If neither the base prices are to be written out, nor a policy scenario with elastic demands to be run, the user should not set the TIMESED control variable.

3.2.2 General equilibrium [MACRO]

The general equilibrium mode of TIMES can be activated in two different ways, using the following MACRO control switch settings:

`$SET MACRO YES`	– activate the standard MACRO formulation
`$SET MACRO MSA`	– activate the MACRO decomposition formulation
`$SET MACRO MLF`	– activate the linearized MACRO-MLF formulation

For further information about the standard MACRO formulation, see the TIMES-MACRO documentation available at the ETSAP site: http://www.iea-etsap.org/web/documentation.asp

In all three formulations, the use of the MACRO mode for evaluating policy scenarios requires that so-called demand decoupling factors (DDF) and labor growth rates first have to be calibrated for the Baseline scenario and corresponding GDP growth projections. When using the standard MACRO or the Macro-MSA formulation, the calibration produces a file containing the calibrated parameters, which must then be included in the policy scenarios to be evaluated. When using the Macro-MLF formulation, the calibration is done on-the-fly.

Until TIMES v3.3.9, the standard MACRO formulation included a separate utility for calibrating the DDF factors and labor growth rates (see the TIMES-MACRO documentation for details). However, the calibration is much easier using the new MACRO decomposition formulation, where you can use the following MACRO control switch setting for carrying out the Baseline calibration:

`$SET MACRO CSA` – calibration with the MACRO decomposition method

The "CSA" calibration facility produces a file called MSADDF.DD, which is automatically included in any subsequent policy run activated by the MACRO=MSA control switch. In order to carry out the calibration, one must also include the necessary MACRO parameters in the model input data (see the TIMES-MACRO documentation for a description of the MACRO parameters). The only mandatory parameters are the initial GDP and GDP growth parameters.

The DDF file produced by CSA can be used for the original TIMES-MACRO formulation, where one may re-calibrate it a few times more with the Baseline scenario to verify the calibration for TIMES-MACRO. The re-calibration is automatically done by TIMES-MACRO at the end of each run, whereupon a new file DDFNEW.DD is written, which can then be renamed for inclusion in the subsequent TIMES-MACRO policy runs.

When using the Macro-MLF formulation, the Macro equations are calibrated on-the-fly when running any policy scenario. Therefore, no dedicated Macro calibration run is needed for using Macro-MLF, but only a standard Baseline model run is required for obtaining the Base prices, in the same way as when using elastic demands (TIMESED).

When using the MACRO decomposition formulation (with MACRO=MSA or MACRO=CSA), and when the partial equilibrium runs of the Baseline and policy scenarios have already been made, using the LPOINT/RPOINT control settings (in combination with SPOINT) may also be useful (see Section 3.8 and 3.12). If the RPOINT setting is used, the initial solution for the decomposition algorithm is taken directly from the GDX file without having to re-run the previously solved LP model again.

3.3 Controls affecting the objective function

3.3.1 Objective function cost accounting [OBJ]

The user can choose to use several alternative objective function formulations instead of the standard objective function. See Part I, Section 5.3.4 and the documentation for the Objective Function Variants for details. The alternative objective formulations can be activated using the $SET OBJ <option> as described in Table 6.

Table 6: Objective Function Formulation Options

OBJ Option	Description
ALT	Uses modified capacity transfer coefficients that improve the independency of investment costs on period definitions.
AUTO (default)	TIMES automatically selects the objective function among the standard formulation or the 'MOD' alternative formulation according to the B(t) and E(t) parameters specified by the user. If those parameters comply with the assumptions used in the standard formulation, then the standard formulation is used, but if not then the alternative formulation 'MOD' is used.

OBJ Option	Description
LIN	Assumes linear evolution of flows and activities between Milestone years, but is otherwise similar to the ALT formulation.
MOD	Period boundaries B(t) and E(t) are internally set to be halfway between Milestone years, giving flexibility to set Milestone years to be other than the middle of each period. Investments in Cases I.1.a and I.1.b only of the objective function investment decision are spread somewhat differently across years.
STD	To ensure that the standard formulation is unconditionally used, even if the B(t) and E(t) parameters do not comply with the standard assumptions.

3.3.2 Objective function components

In addition to controlling how the objective function is assembled, as described in the previous section, the user has control of the handling of specific components of the objective functions, as described in Table 7.

Table 7: Objective Function Component Options

Option <value>	Description
DAMAGE <LP(default) /NLP/NO>	The TIMES model generator supports the inclusion of so-called damage costs in the objective function. By default, if such damage costs have been defined in the model input data, they are also automatically included in the objective function in linearized form (LP). However, if the user wishes the damage costs to be included in the solution reporting only, the DAMAGE control variable can be set to 'NO'. Non-linear damage functions can be requested by setting the control variable to 'NLP'. See Part II, Appendix B, for more on the damage cost function extension.
OBJANN <YES>	Used for requesting a period-wise objective formulation, which can be used e.g. together with the MACRO decomposition method for enabling the iterative update of the period-wise discount factors (See the documentation titled *Macro MSA*, on the MACRO Decomposition Algorithm, for details).

Option <value>	Description
OBLONG <YES/NO>	In the STD (standard) and MOD (alternative) objective function formulations discussed in Table 6 the capacity-related costs are not completely synchronized with the corresponding activities, which may cause distortions in the accounting of costs. This switch causes all capacity-related cost to be synchronized with the process activities (which are assumed to have oblong shapes), thereby eliminating also the small problems in salvaging that exist in the STD and MOD formulations. Due to the obvious advantages of using this setting, the OBLONG setting is activated by default whenever the MOD formulation is used. However, for backwards compatibility, one can disable it by adding the explicit setting $SET OBLONG NO in the run file. Using the OBLONG setting can be recommended also with the STD and AUTO settings. It can even be used with the ALT and LIN settings, but that is not recommended.
MIDYEAR <YES>	In the standard objective formulation, both the investment payments and the operating cost payments are assumed to occur at the beginning of each year within the economic/technical lifetime of technologies. This also means that the so-called annuities of investment costs are calculated using the following formula, where r is the discount rate (see Part II, Section 6.2 for more on the objective function): $CRF = (1–(1+r)^{-1})/(1–(1+r)^{-L})$ According to this formula, the interest costs are zero if the lifetime L of the technology is only one year, because the payments are assumed to occur at the beginning of each year. This approach is often called as ***beginning-of-year*** discounting. However, it leads to an underestimation of the costs, because in reality the investments can be paid back only after getting some income from the investment. To avoid such underestimation, the following formula for annuities is perhaps more commonly used: $CRF = r/(1–(1+r)^{-L})$ This second formula effectively assumes that the annual investment payments occur at the end of each year. This approach is often called as ***end-of-year*** discounting. As a good compromise between these two approaches, and highly recommended by many guidelines on good practices in cost evaluations[19], so-called ***mid-year discounting*** can additionally be used. See Section 6.2.12 of Part II for more information about mid-year discounting.

[19] For example, by the U.S. government:
http://www.whitehouse.gov/omb/circulars/a094/a094.html

Option <value>	Description
DISCSHIFT	As a generalization to the MID_YEAR setting, alternate time-of-year discounting, including the end-of-year discounting mentioned above, can be achieved by using the DISCSHIFT control variable. The control variable should be set to correspond to the amount of time (in years) by which the discounting of continuous streams of payments should be shifted forward in time, with respect to the beginning of operation. Setting it to the value of 0.5 would be equal to the setting $SET MID_YEAR YES, and setting it to the value of 1.0 would be equal to end-of-year discounting, as follows: $SET DISCSHIFT 1
VARCOST <LIN>	The standard dense interpolation and extrapolation of all cost parameters in TIMES may consume considerable amounts of memory resources in very large models. In particular, the variable costs, which may also be to a large extent levelized onto a number of timeslices, usually account for the largest amount of cost data in the GAMS working memory. If desired, TIMES can be advised to interpolate and extrapolate the variable cost parameters only sparsely for the Milestone years. The values at the intermediate years will then be derived "*on the fly*", by piecewise linear interpolation, and will not be stored in the GAMS memory. This option may thus be useful when running very large models on computers with limited memory.

3.4 Stochastic and sensitivity analysis controls

3.4.1 Stochastics [STAGES]

The stochastic mode of TIMES can be activated with the STAGES control variable, by using the following setting:

```
$SET STAGES YES
```

This setting is required for using the multi-stage stochastic programming features of TIMES. It can also be used for enabling sensitivity and tradeoff analysis features. See Part I for more details on stochastic programming and tradeoff analysis in TIMES.

3.4.2 Sensitivity [SENSIS]

Many useful sensitivity and tradeoff analysis features are available in TIMES, and they can be enables by activating the stochastic mode of TIMES (see above). However, such sensitivity and tradeoff analyses are often based on running the model in a series of cases that differ from each other in only in a few parameter values. In such cases the so-called warm start features can usually significantly speed up the model solution in the successive runs.

The use of the warm start facilities can be automatically enabled in sensitivity and tradeoff analysis by using the following setting instead of $SET STAGES YES:

```
$SET SENSIS YES
```

As the variables then remain the same, warm start is automatically enabled by GAMS according to the BRATIO value (BRATIO can be set in VEDA-FE, or added manually to the ANSWER GEN template as a $OPTION BRATIO=1; as well).

See the documentation on stochastic programming and tradeoff analysis in TIMES for more information on the use of this switch. The documentation is available at the ETSAP site: http://www.iea-etsap.org/web/documentation.asp

3.4.3 Hedging recurring uncertainties [SPINES]

For modeling recurring uncertainties, such as hydrological conditions or fuel-price volatilities, the stochastic mode can be activated also in such a way that the SOW index will be inactive for all capacity-related variables (VAR_NCAP, VAR_CAP, VAR_RCAP, VAR_SCAP, VAR_DRCAP, VAR_DNCAP). This modification to the standard multi-stage stochastic formulation makes it possible to use the stochastic mode for hedging against recurring uncertainties, and for finding the corresponding optimal investment strategy.

This variant of the stochastic mode can be activated by using the following control variable setting:

```
$SET SPINES YES
```

In addition, under the SPINES option all the remaining equations that define dynamic or cumulative relationships between variables can additionally be requested to be based on the expected values instead of imposing the inter-period equations separately for each SOW. Doing so will ensure that the uncertainties represented by the SOW-indexed variables will be independent in successive periods. This further model simplification can be requested by using the SOLVEDA switch, as follows:

```
$SET SOLVEDA 1
```

In addition, under the SPINES option this SOLVEDA setting will, for now, also cause all the results for the activities and flows to be reported on the basis of the expected values only, and not separately for each SOW. After all, the recurring uncertainties are rather aleatory by nature, and therefore the user should probably be most interested in the optimal investment strategy, and only in the average or normal year results for the activities and flows. If requested, an option to produce results for all SOWs even under the period-independent variant can later be added.

Unlike the basic stochastic option STAGES, the SPINES option may be used also together with the time-stepped mode (see Section 3.5.2).

The SPINES control variable is available only in TIMES versions 3.3.0 and above, and should currently be considered ***experimental*** only.

3.5 Controls for time-stepped model solution

3.5.1 Fixing initial periods [FIXBOH]

The purpose of the FIXBOH option is to bind the first years of a model run to the same values determined during a previous optimization. The approach first requires that a reference case be run, and then by using FIXBOH the model generator sets fixed bounds for a subsequent run according to the solution values from the reference case up to the last Milestone year less than or equal to the year specified by the FIXBOH control variable. The FIXBOH control has to be used together with the LPOINT control variable, in the following way:

```
$SET FIXBOH 2050
$SET LPOINT <run_name>
```

Here, the value of FIXBOH (2050) specifies the year, up to which the model solution will be fixed to the previous solution, and the value of LPOINT (run_name) specifies the name of the previous run, from which the previous solution is to be retrieved. Consequently, either a full GDX file or a GAMS "point file" (see section 3.8) from the previous run should be available. If no such GDX file is found, a compiler error is issued. The Milestone years of the previous run must match those in the current run.

As a generalization to the basic scheme described above, the user can also request fixing to the previous solution different amounts of first years according to region. The region-specific years up to which the model solution will be fixed can be specified by using the TIMES REG_FIXT(reg) parameter. The FIXBOH control variable is in this case treated as a default value for REG_FIXT.

Example: Assume that you would like to analyze the 15-region ETSAP TIAM model with some shocks after the year 2030, and you are interested in differences in the model solution only in regions that have notable gas or LNG trade with the EU. Therefore, you would like to fix the regions AUS, CAN, CHI, IND, JPN, MEX, ODA and SKO completely to the previous solution, and all other regions to the previous solution up to 2030.

In the RUN file you should specify the control switches described above:

```
$SET FIXBOH 2030
$SET LPOINT <run_name>
```

In a model DD file you should include the values for the REG_FIXT parameter:

```
PARAMETER REG_FIXT /
AUS      2200,  CAN   2200, CHI     2200, IND     2200
JPN      2200, MEX    2200, ODA     2200, SKO     2200
/;
```

3.5.2 Limit foresight stepwise solving [TIMESTEP]

The purpose of the TIMESTEP option is to run the model in a stepwise manner with increasing model horizon and limited foresight. The TIMESTEP control variable specifies the number of years that should be optimized in each solution step. The total model horizon will be solved by successive steps, so that in each step the periods to be optimized are advanced further in the future, and all periods before them are fixed to the solution of the previous step. Figure 17 illustrates the step-wise solution approach.

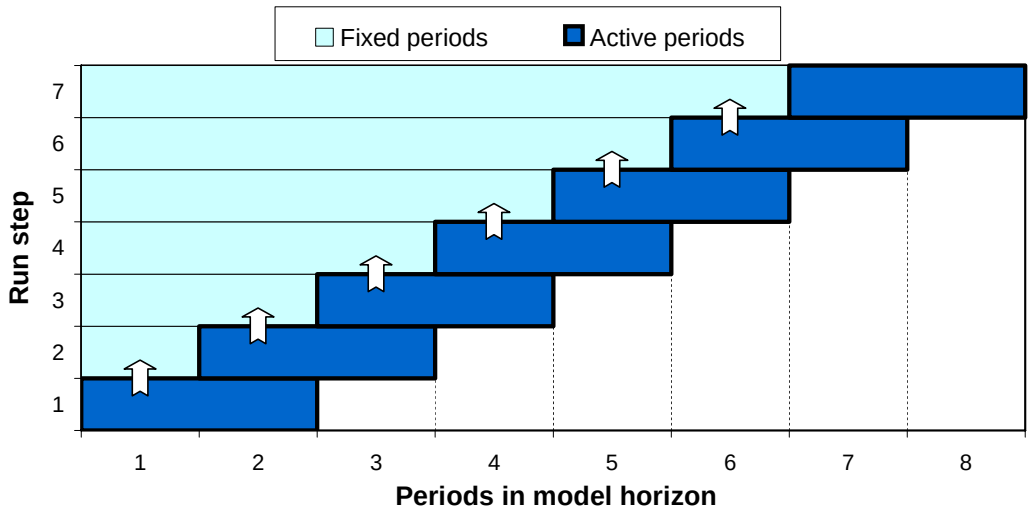


Figure 17: Sequence of Optimized Periods in Time-stepped Solution

The amount of overlapping years between successive steps is by default half of the active step length (the value of TIMESTEP), but it can be controlled by the user by using the TIMES G_OVERLAP parameter. Consequently, the specifications that can be used to control a stepped TIMES solution are the following:

```
$SET TIMESTEP 20                (specified in the run file)
PARAMETER G_OVERLAP / 10 /;     (specified in a DD file)
```

In this example, the TIMESTEP control variable specifies the active step length of each successive solution step (20 years), and the G_OVERLAP parameter specifies the amount of years, by which the successive steps should overlap (10 years). They may be set in the VEDA-FE Control Panel, like almost all control switches, or in ANSWER by manually adding the parameter to the Run GEN Template.

Because the time periods used in the model may be variable and may not always exactly match with the step-length and overlap, the actual active step-lengths and overlaps may somewhat differ from the values specified. At each step the model generator tries to make a best match between the remaining available periods and the prescribed step length. However, at each step at least one of the previously solved periods is fixed, and at least one remaining new period is taken into the active optimization in the current step.

3.6 TIMES extensions

3.6.1 Major formulation extensions

There are several powerful extensions to the core TIMES code that introduce advanced modeling features. The extension options allow the user to link in additional equations or reporting routines to the standard TIMES code, e.g. the DSC extension for using lumpy investments. The entire information relevant to the extensions is isolated in separate files from the standard TIMES code. These files are identified by their extensions, e.g. ***.DSC** for lumpy investments or ***.CLI** for the climate module. The extension mechanism allows the TIMES programmer to add new features to the model generator, and test them, with only minimal hooks provided in the standard TIMES code. It is also possible to have different variants of an equation type, for example of the market share equation, or to choose between different reporting routines, for example adding detailed cost reporting. The extension options currently available in TIMES are summarized in Table 8.

VEDA-FE Case Manager and ANSWER Run Model Options form along with the GEN template will both set the appropriate switches and augment the initialization calls, as described in Table 8 (unless noted otherwise), with the user being fully responsible to provide the necessary data for each extension option employed in a run.

Table 8: TIMES Extension Options

Extension	Description
ABS	Option to use the Ancillary Balancing Services extension. It is activated with the following setting in the <case>.run file: `$SET ABS YES` See the separate documentation on the ABS extension for more information.
CLI	The climate module estimates change in CO_2 concentrations in the atmosphere, the upper ocean including the biosphere and the lower ocean, and calculates the change in radiative forcing and the induced change in global mean surface temperature. It is activated with the following setting in the <case>.run file: `$SET CLI YES` See Parts I–II for more information on the use of the Climate Module and this switch.
DSC	Option to use lumpy investment formulation. Since the usage of the discrete investment options leads to a Mixed-Integer Programming (MIP) problem, the solve statement in the file solve.mod is automatically altered by the user shell. To activate this extension manually, the following control switch needs to be provided in the <Case>.run file : `$SET DSC YES` See Part I, Chapter 10 for more information on the use of Lumpy Investment.

Extension	Description
DUC	Option to use the discrete unit commitment formulation. To activate this extension manually, the following control switch needs to be provided in the <Case>.run file : `$SET DUC YES` See separate documentation on Dispatching and unit commitment features in TIMES for more information on the use of the discrete unit commitment option.
ECB	Option to use the Economic Choice Behavior extension (logit market sharing mechanism). To activate this extension, the following control switch needs to be provided in the <Case>.run file, as follows: `$SET ECB YES` See related user note for more information on the use of this extension.
ETL	Option to use endogenous technology learning formulation. Since the usage of this option leads to a Mixed-Integer Programming (MIP) problem, the solve statement in the file solve.mod is automatically altered by TIMES. To activate this extension manually, the following control switch needs to be provided in the <Case>.run file, as follows: `$SET ETL YES` See Parts I–II for more information on the use of Endogenous Technology Learning.
MACRO	Option to use the MACRO formulation. Since the usage of the MACRO options leads to a Non-linear Programming (NLP) problem, the solve statement in the file solve.mod has to be altered. To activate this extension manually, the $SET MACRO <value> control switch needs to be provided in the <Case>.run file, with the following valid values: • YES – activate the integrated MACRO algorithm • MSA – activate Macro decomposition algorithm (MSA) • CSA – activate the calibration algorithm for MSA • MLF – activate the integrated Macro-MLF formulation See the separate MACRO documentation for more on using these options.
MICRO	Option to use the non-linear elastic demand formulation. To activate this extension manually, the following control switch needs to be provided in the <Case>.run file : `$SET MICRO YES` See Part II for more information on demand function formulations.
RETIRE	The RETIRE control variable can be used for enabling early and lumpy retirements of process capacities. The valid switch values for this control variable are: • NO – Disables all early and lumpy retirements; • LP – Enables continuous early retirements for all those processes that are

Extension	Description
	included in the set PRC_RCAP(r,p); • MIP – Enables early retirements for the processes that are included in the set PRC_RCAP(r,p), and additionally enables the retirements to be lumpy for those of these processes that also have RCAP_BLK (the lumpy block size) defined, and • YES – Enables early retirements for any processes that have at least one instance of the parameter RCAP_BND defined. In this variant, activating lumpy retirements for those processes that have also RCAP_BLK defined requires that the setting $SET DSC YES is used as well. Consequently, when using the $SET RETIRE YES switch, using the set PRC_RCAP is not needed at all (and it will have no effect). See Part II for more information on the use of the Early Retirement feature.
VDA	The VDA control variable can be used to enable the VDA pre-processor extension of TIMES, which implements new features and handles advanced parameters specified by VEDA-FE/ANSWER that are transformed into their equivalent TIMES core parameters to make specification easier (e.g., VDA_FLOP becomes FLO_FUNC/FLO_SUM), with the following setting: `$SET VDA YES` The VDA extension is always automatically enabled by both VEDA-FE and ANSWER. The attributes implemented are documented in Part II.

3.6.2 User extensions

Besides the core extensions discussed in the previous section, the model management system allows user extensions to be introduced for extended pre-processing of advanced parameter specifications that make the specification of (complex) input parameters much simpler, and to refine features describing technology operations (e.g., for CHPs).

The user extension(s) that are to be included in the current model run need to be activated in the <case>.run file, and passed to inimty.mod, e.g.:

```
$BATINCLUDE initmty.mod IER FIA
```

As shown in this example, it is possible to add several extension in the $BATINCLUDE line above at the same time. In this case two user extensions, IER and FIA, are incorporated with the standard TIMES code.

The GAMS source code related to an extension <ext> has to be structured by using the following file structure in order to allow the model generator to recognize the extension[20] (see

[20] This structure is only of interest for those modellers who want to programme their own extensions. The modeller who uses an extension in his model does not need to know these programming details.

also Section 2.2). The placeholder <ext> stands for the extension name, e.g. CLI in case of the climate module extension.

- **initmty.<ext>**: contains the declaration of new sets and parameters, which are only used in the context of the extension;
- **init_ext.<ext>**: contains the initialization and assignment of default values for the new sets and parameters defined in initmty.<ext>;
- **prep_ext.<ext>**: contains primarily calls to the inter-/extrapolation routines (prepparm.mod, fillparm.mod);
- **pp_prelv.<ext>**: contains any preprocessing after inter-/extrapolation but before levelizing;
- **ppm_ext.<ext>**: contains any preprocessing after levelizing of standard parameters but before calculation of equation coefficients; it might contain calls to levelizing routines for the new input parameters implemented in the extension;
- **coef_ext.<ext>**: contains coefficient calculations used in the equations or reporting routines of the extension;
- **mod_vars.<ext>**: contains the declaration of new variables;
- **equ_ext.<ext>**: contains new equations of the extension;
- **mod_ext.<ext>**: adds the new defined equations to the model;
- **rpt_ext.<ext>**: contains new reporting routines.

Not of all these files have to be provided when developing a new extension. If for example no new variables or no new report routines are needed, these files can be omitted.

An example of a user extension is the IER extension included in the TIMES distribution. It contains several extensions to the equation system introduced specifically for the modelling needs by Institute for Energy Economics and the Rational Use of Energy (IER, University of Stuttgart), such as market/product share constraints, and backpressure/condensing mode full load hours.

3.7 The TIMES reduction algorithm

The motivation of the reduction algorithm is to reduce the number of equations and variables generated by the TIMES model, reducing memory usage and solution time. Since there is no downside the having the TIMES reduction algorithm applied by the pre/post-processors, it is the default set via VEDA/ANSWER.

An example for a situation where model size can be reduced is a process with one input and one output flow, where the output flow variable can be replaced by the input variable times the efficiency. Thus the model can be reduced by one variable (output flow variable) and one equation (transformation equation relating input and output flow).

3.7.1 Reduction measures

The effects arising from activating the reduction algorithm are each described below.

1. Process without capacity related parameters does not need capacity variables:
   - No capacity variables **VAR_CAP** and **VAR_NCAP** created.
   - No **EQL_CAPACT** equation created.
2. Primary commodity group consists of only one commodity:
   - Flow variable **VAR_FLO** of primary commodity is replaced by activity variable.
   - No **EQ_ACTFLO** equation defining the activity variable created.
3. Exchange process imports/exports only one commodity:
   - Import/Export flow **VAR_IRE** can be replaced by activity variable (might not be true if exchange process has an efficiency).
   - No **EQ_ACTFLO** equation defining the activity variable created.
4. Process with one input and one output commodity:
   - One of the two flows has to define the activity variable. The other flow variable can be replaced by the activity variable multiplied/divided by the efficiency.
   - No **EQ_PTRANS** equation created.
5. An emission flow of a process can be replaced by the sum of the fossil flows multiplied by the corresponding emission factor:
   - No flow variables for the emissions created
   - No **EQ_PTRANS** equation for the emission factor.
6. Upper/fixed activity bound **ACT_BND** of zero on a higher timeslice level than the process timeslice level is replaced by activity bounds on the process timeslice level. Thus no **EQG/E_ACTBND** equation is created.
7. Process with upper/fixed activity bound of zero cannot be used in current period. Hence, all flow variables of this process are forced to zero and need not be generated in the current period. Also **EQ_ACTFLO** and **EQx_CAPACT** are not generated. If the output commodities of this process can only be produced by this process, also the processes consuming these commodities are forced to be idle, when no other input fuel alternative exists.
8. When a **FLO_FUNC** parameter between two commodities is defined and one of these two commodities defines the activity of the process, the other flow variable can be replaced by the activity variable being multiplied/divided by the **FLO_FUNC** parameter.
   - One flow variable is replaced.
   - No **EQ_PTRANS** equation for the **FLO_FUNC** parameter is created.

3.7.2 Implementation

To make use of the reduction algorithm one has to define the environment variable

```
$SET REDUCE YES/NO
```

in order to turn on/off the reduction. This environment variable controls in each equation where the flow variable occurs whether it should be replaced by some other term or not. If the control variable is not defined at all, the default is to make partial model reduction by eliminating unnecessary capacity variables and substituting emission flows only. This third option can thus be more useful if full model reduction is not wanted.

The possibility of reduction measures is checked in the file pp_reduce.red. If reduction is turned on, flow variables that can be replaced are substituted by a term defined in cal_red.red. The substitution expression for the import/export variable VAR_IRE is directly given in the corresponding equations. In addition the $control statement controlling the generation of the equations EQ_PTRANS, EQ_ACTFLO, EQx_CAPACT has been altered. Also bnd_act.mod has been changed to implement point 6 above.

To recover the solution values of the substituted variables, corresponding parameters are calculated in the reporting routines and are then written to the VEDA-BE file.

3.7.3 Results

The main solution and solver statistics for model runs of a USEPA9r-TIMES model with and without reduction algorithm are given in Table 9 for CPLEX (GAMSv24.4.1), using a call to the solver for Barrier for initial solve and Primal Simplex crossover to finish up.

Table 9: Reduction Model Comparison

Statistic	Reduce Not Set	Reduce=NO	Reduce=YES
Block / Single Equations	92 / 1,652,677	92 / 1,796,525	92 / 870,814
Block / Single Variables	14 / 2,429,348	14 / 2,564,039	14 / 1,645,631
Total Non-Zeros	7,432,490	8,048,546	5,853,371
Generation	49.499 SECONDS	62.681 SECONDS	45.802 SECONDS
Execution	102.462 SECONDS	115.394 SECONDS	95.972 SECONDS
Memory	2,075 MB	2,180 MB	1,957 MB
Iteration Count	126	116	110
Objective Value	88503425.2162	88151566.0679	88503425.2162
Resource Usage / Solution Time	1323.824	2656.557	1320.111

Comparing the non-setting of REDUCE vs. REDUCE=YES the number of equations and variables in the reduction is around 47% lower than in the non-reduced case. Since the smaller number of equations and variables require less memory, the memory usage in the reduction run decreases by 6.4%. The solution time is only reduced slightly compared to the non-reduced model run.

Issues Using the Reduction Algorithm

- In some cases the reduced problem may produce an "optimal solution with unscaled infeasibilities".
- Shadow price of non-generated EQ_PTRANS equations are lost.
- Reduced cost of upper/fixed ACT_BND of zero are lost. If one needs this information, one should use a very small number instead, e.g. 1.e-5, as value for the activity bound.

3.8 GAMS savepoint / loadpoint controls

TIMES includes GAMS control variables that can be used to utilize the GAMS savepoint and loadpoint facilities. The savepoint facility makes it possible to save the basis information (levels and dual values of variables and equations) into a GDX file after model solution. The loadpoint facility makes it possible to load previously saved basis information from a GDX file and utilize it for a so-called warm start to speed up model solution.

The GAMS control variables that can be used for the savepoint and loadpoint features in TIMES models are SPOINT and LPOINT. These control variables are ***completely optional***, but can be set in the following ways as described in Table 10 if desired:

Table 10: Save/Load Restart Switches

Option	Description
SPOINT	
Not provided (default)	Does not save or load a restart point.
1 (or YES)	The final solution point from the model run should be saved in the file %RUN_NAME%_p.gdx, where %RUN_NAME% is the GAMS control variable that should always be set to contain the name of the current TIMES model run in the run file for the model.

Option	Description
2	The model generator should make an attempt to load the solution point from the file %RUN_NAME%_p.gdx, where %RUN_NAME% is the GAMS control variable that should always be set to contain the name of the current TIMES model run in the run file for the model. If the control variable LPOINT has additionally been set as well, this attempt will be made only if the loading from the file %LPOINT%_p.gdx fails.
3	Combines both of the functionalities of the settings 1 and 2.
LPOINT	
LPOINT filename	Indicates that the model generator should load the solution point from the file %LPOINT%_p.gdx. If the control variable SPOINT has additionally been set to 2 or 3, a subsequent attempt to load from %RUN_NAME%_p.gdx is also made if the loading from the file %LPOINT%_p.gdx fails.

In VEDA-FE the LPOINT can be set from the Case Manager by requesting the loading of a previously GDX, and in ANSWER by means of Run Model Restart files specifications, as shown in Figure 18.

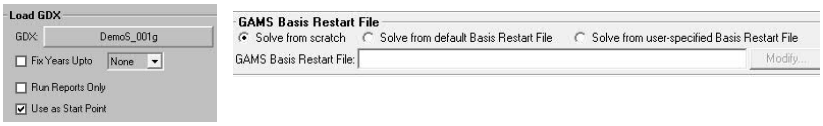


Figure 18 - Setting LPOINT

3.9 Debugging controls

By using the DEBUG control, the user can request dumping out all user/system data structures into a file, and turn on extended quality assurance checks. The switch is activated by means of:

```
$SET DEBUG YES
```

with actions performed according to the settings described in Table 11.

Table 11: Debug Switches

Switch <value>	Description
DUMPSOL YES	Dump out selected solution results into a text file (levels and marginals of VAR_NCAP, VAR_CAP, VAR_ACT, VAR_FLO, VAR_IRE, VAR_SIN, VAR_SOUT, VAR_COMPRD, EQG_COMBAL, EQE_COMBAL, EQE_COMPRD).

Switch <value>	Description
SOLVE_NOW NO	Only check the input data and compile the source code, but do not solve the model.
XTQA YES	Turn on extended quality assurance checks [this setting is automatically enabled whenever $SET DEBUG YES is used].

3.10 Controls affecting solution reporting

The various $<switch> <value> switches controlling reporting of the model results are summarized in Table 12.

Table 12: Solution Reporting Switches

Switch <value>	Description
ANNCOST LEV	Until TIMES v3.4.9, the values reported for each of these cost components have been calculated strictly for the associated Milestone year of a period. However this can result in investments made in other years within a period not being reflected, and for longer periods may not properly reflect changes in the other annual expenditures over that timeframe. A consequence of this is that it has not been possible to reconstruct the objective function value from the annualized costs reported. Additionally, these reported costs cannot be thought of as "representative" of the entire period, but only of the Milestone year. To redress this, from TIMES v3.5.0 the annual costs based upon the levelized costs over process lifetimes or periods can be requested. The various annualized cost report parameters are found in Table 13. In this way all expenditures during the period are captured and the total objective function can be reconstructed from the levelized annual costs with a very high accuracy (when using $SET OBLONG YES). There is also a new attribute Time_NPV, which gives the period-wise discount factors, and a UC tag = LEVCOST/COST indicating whether the annual costs reported for each scenario are levelized or not. That is, when said Attribute = LEVCOST for a scenario, then the annualized costs for said scenario represent the levelized average annual values.
BENCOST YES	TIMES includes also a basic benefit-cost reporting for new technologies. When the benefit-cost reporting is requested, the TIMES reporting attribute VAR_NCAPR includes the benefit-cost indicators listed in Table 14.

Switch <value>	Description
RPT_FLOTS COM / ANNUAL	Used for controlling the timeslices that will be used for reporting the levels of the TIMES flow variables. By default, the timeslices of the original TIMES flow variables are used also for reporting. However, in many cases it may be more desirable to have all the flow levels reported at the commodity timeslices (COM), or, for very large models, at the ANNUAL timeslice only. The RPT_FLOTS setting has no effect on the reporting of marginal costs for flows.
SOLANS YES	Produce the solution reports that can be imported into the ANSWER.
SOLVEDA YES / 1	Prepare the solution reporting values that are to be imported into the VEDA-BE. The standard setting is $SET SOLVEDA YES, which works with all TIMES extensions. Sometimes it may be useful to request that TIMES reports also the results from non-stochastic runs with an extra dummy SOW index '1', such that the results can be imported into a database that contains results from both deterministic and stochastic runs. The inclusion of the extra index can be activated by the setting $SET SOLVEDA 1.
XTQA YES	Turn on extended quality assurance checks [this setting is automatically enabled whenever $SET DEBUG YES is used].

Table 13: Solution Cost Reporting Attributes

Attribute	Description
Cost_Act	Annual activity costs, plus start-up, shut-down and ramping costs when defined
Cost_Comx	Annual commodity taxes/subsides
Cost_Els	Annual loss of consumer surplus (for elastic demand)
Cost_Flo	Annual flow costs (including import/export prices)
Cost_Flox	Annual flow taxes/subsidies
Cost_Fixx	Annual fixed operating and maintenance taxes/subsidies
Cost_Fom	Annual fixed operating and maintenance costs
Cost_Inv	Annual investment costs
Cost_Invx	Annual investment taxes/subsidies
Cost_ire	Annual implied costs of endogenous trade
Cost_Salv	Salvage values of capacities at EOH+1
Reg_ACost	Regional annual costs by component

Table 14: BENCOST Reporting Attributes

Attribute	Description
COST	the total unit costs of VAR_NCAP (in terms of investment costs)
COST	the total unit costs of VAR_NCAP (in terms of investment costs)
CGAP	competitiveness gap (in terms of investment costs), obtained directly from the VAR_NCAP marginals (and optional ranging information)
GGAP	competitiveness gap (in terms of investment costs), obtained by checking also the VAR_ACT, VAR_FLO and VAR_CAP marginals, in case VAR_NCAP happens to be basic at zero
RATIO	benefit / cost ratio, based on CGAP
GRATIO	benefit / cost ratio, based on GGAP
RNGLO	ranging information (LO) for VAR_NCAP (when CPLEX ranging is activated; in terms of investment costs)
RNGUP	ranging information (UP) for VAR_NCAP (when CPLEX ranging is activated; in terms of investment costs

For the BENCOST report, all of the absolute indicators are expressed in terms of undiscounted investment costs (like those specified by NCAP_COST). For example, the competitiveness gap represents the amount of change in investment costs that would bring the technology competitive (the VAR_NCAP variable would enter the solution basis). Ranging information can only be reported when the CPLEX ranging option has been used. The ranging option can be activated by adding the following two lines into the CPLEX options file (CPLEX.OPT):

```
objrng VAR_NCAP
rngrestart timesrng.inc
```

When available, the LO ranging information is also used for calculating the competitiveness gap indicators, because the VAR_NCAP variables can occasionally be basic at zero, making the reduced cost information useless. In such cases the LO ranging value can be used to derive the amount of change required in the VAR_NACP cost coefficient to cause a change in the basis.

3.11 Reporting options activated by RPT_OPT

Various reporting options can also be set by specifying values for the RPT_OPT parameter. Although it is actually not a GAMS control variable, for completeness it is described here. Like the control switches, these options can be specified in the RUN file, but they can also be included in the DD files, if the user shell implements their use that way. Specifying the options in the RUN file can be done with any of the three following alternative ways:

- $SET RPT_OPT KEY1.N1 <value1>, KEY2.N2 <value2>, ….
- PARAMETER RPT_OPT / KEY1.N1 <value1>, KEY2.N2 <value2>, …. /;
- RPT_OPT('KEY1','N1') = <value1>; RPT_OPT('KEY2','N2') = <value2>; …

Here, KEY1, KEY2, … refer to the main option group and N1, N2, … refer to sub-groups within that group, as indicated in Table 15.

Table 15: RPT_OPT Options Settings

Option group	Sub-group	Value	Description
ACT	2	<0	Suppress reporting of activity marginals
ACT	9	>0	Filter out process activities less in value than the RPT_OPT value
CAP	9	>0	Filter out process capacities less in value than the RPT_OPT value
FLO	1	>0	Report process flows at commodity TS level
FLO	3	>0	Report value flows by process (implies (FLO,1)=1)
FLO	5	>0	Report electricity supply by energy source
FLO	7	>0	Report process topology indicators
FLO	9	>0	Filter out process flows less in value than the RPT_OPT value (in absolute terms)
COMPRD	1	>0	Report VAR_COMPRD for all commodities
COMPRD	4	>0	Report PRC_MARK constraint marginals in PAR_UCMRK (User_conFXM in VBE)
NCAP	1	<>0	Activate levelised cost calculation (see Part II for details)
NCAP	9	>0	Filter out process new capacities less in value than the RPT_OPT value
OBJ	1	<>0	Split investment costs according to hurdle rate, and report present values of costs by process and commodity (CST_PVP / CST_PVC)
OBJ	2	>0	Report annualized investment costs in terms of costs levelized over the technical life (as with $SET ANNCOST LEV)
COM_TYPE	3	< 0	Report process flows of type COM_TYPE at the ANNUAL level
NRG_TYPE	1	>0	Report the power levels of process flows of NRG subtype NRG_TYPE at COM_TSL level in the P_Out attribute (Var_Pout in VEDA-BE). The value is taken as the conversion factor from the capacity to the flow unit (e.g. 31.536 for PJ/GW).

NRG_TYPE	3	<>0	Report process flows of NRG subtype NRG_TYPE at the ANNUAL level (<0) or at COM_TSL level (> 0, overriding option). With Value=2 one can enable reporting of input flow levels in conjunction with using also sub-group 1.

3.12 Miscellaneous controls

Various other $<option> switches control miscellaneous aspects of a TIMES model run, as described Table 16.

Table 16: Miscellaneous Control Options Settings

Option <value>	Description
BOTIME / EOTIME <year>	These controls can be used for adjusting the total available time span of years available in the model. All years related to the data and model must lie between BOTIME and EOTIME, inclusive. The default for BOTIME ('Beginning of Time') is 1850 and the default for EOTIME ('End of Time') is 2200. [A large model may see slightly faster runtimes if the BO/EOTIME horizon is narrowed to that actually needed for the model run.]
DATAGDX <YES>	This control can be used for requesting all the model input data to be dumped into a GDX file named <RUN_NAME~Data_yymmdd>.GDX, which is saved immediately after all data has been read in, at the beginning of executing the main driver (maindrv.mod). If domain violation warnings have been issued, the GDX file is subsequently used for re-reading the input data with the domain violations filtered. It can also be used for reading all the input data from an existing GDX file in the work folder, which must be then named <RUN_NAME~Data>. In that way, the model data saved from an earlier run can also be used in a new TIMES run, either completely instead of using *.DD data files, or with some new *.DD files merged with the data read from the GDX file. Only the timeslice definition must still be read from a *.DD file.
DYNTS <YES>	This control can be used for enabling dynamic timeslice configurations. Dynamic timeslices means that the timeslice tree can be varied according to model period. See the related user note for more information on the use of dynamic timeslice configurations.

Option <value>	Description
GDX_IREBND / GDX_IPRIC <file>	These control flags can be used to import bounds and prices on exogenous imports/exports from a previous run, and thereby override any user-defined bounds/prices. Only bounds and prices for such imports and exports flows are imported that were endogenous in the previous run but are exogenous for the current run. The first setting tells TIMES to import the flow-levels of imports and exports from the file 'boundfile.gdx', and use these levels as fixed bounds on the imports and exports in the current run (if they are exogenous in the current run and were endogenous in the earlier run). The second setting tells TIMES to import the marginal prices of imports and exports from the file 'pricefile.gdx', and define these prices on the imports and exports in the current run (if they are exogenous in the current run and were endogenous in the earlier run). The earlier run may have different Milestone years than the current run.
PUNITS <YES>	Used for generating process units info (activity & capacity). The output attribute is `PRC_UNITS(r,p,type,units)`, where type=`'ACT'/'CAP'`.
RELAX_PRC_CG <YES>	Used to relax the requirement that all genuine commodity groups that are used in process-related attributes have to be explicitly associated with the processes, using the set PRC_CG. All PRC_CG definitions can be omitted in the model when the setting is enabled.
RPOINT <YES>	Used for reproducing the solution of a previous run, without actually solving the model at all. It should be used together with the LPOINT control, which specifies the GDX file where the previous solution is retrieved. The model generator then only loads the solution and generates the reports.
SHELL <ANSWER>	Indicates the ANSWER-TIMES user shell is being used for running this TIMES models.
STSFLX <YES>	Enables the experimental flexible general storage (STS) formulation, which has an enhanced approach for capturing the operational flexibility. See the related user note for more information on this option.
VALIDATE <YES>	A greatly simplified formulation of the objective function and capacity constraints, emulating the MARKAL model generator, may be requested – however, use of the VALIDATE control switch is discouraged.

Option <value>	Description
VAR_UC <YES>	Used to enable or disable the explicit use of slack variables in user constraints. By default, no explicit slack variables are used and all the user constraints are either equalities or inequalities, depending on the bound type specified. However, if the slack variables are enabled, all the user constraints are defined as equality constraints, using bounds on the slack variables to define the actual type of the constraint. This can be useful for e.g. more efficient specification of ranges, and is required when using the stochastic or sensitivity modes.
VINTOPT <1 / 2>	Any technology characteristics defined for a vintaged process describe the characteristics of new capacity installed in the year specified. However, in TIMES the characteristics at the Milestone year are by default used for all the capacity installed in the corresponding period, which can lead to accelerated technology development, depending on the lengths of periods. To avoid such distortions caused merely by period length definitions setting VINTOPT 1 is used, all vintaged characteristics of technologies are automatically adjusted so that the average characteristics of new capacity installed for each period correspond to the original data. When the setting VINTOPT 2 is used, all vintaged processes are modeled using a different approach, which preserves the average characteristics of new capacity installed for each period, as originally defined by the TIMES attributes. The VINTOPT control variable is currently for experimental use only.
WAVER <YES>	Usually the TIMES model generator interpolates the user-defined time-series data only for the Milestone years, and then uses the value at the Milestone year as a representative value for the whole period. An important exception to this common rule are the cost parameters, which are all interpolated densely, and are thus always fully taken into account. However, in some cases it might be desirable to have some other parameters densely interpolated, such that the calculated weighted average over each projection period would be used as the representative value for the period, instead of the value at the Milestone year. Perhaps the most suitable candidates for applying this kind of an interpolation method are parameters representing projected absolute values, such as demands or remaining residual capacities. There is a switch for activating the Weighted Average Interpolation method described above, to be applied for the demand projections (COM_PROJ) and residual capacities (PRC_RESID), as well as the NCAP_PASTI parameters reflecting the available capacity of the installation period.