

# TIMES Endogenous Technology Learning (ETL) Extension in ANSWER-TIMES

## Introduction

The purpose of this note is to briefly describe how to invoke the TIMES Endogenous Technology Learning (ETL) Extension in ANSWER-TIMES.

For an explanation of the TIMES Endogenous Technology Learning (ETL) Extension see:

- Chapter 8 of “Documentation for the TIMES Model – Part I” (authors Richard Loulou, Uwe Remme, Amit Kanudia, Antti Lehtila, Gary Goldstein), which can be downloaded from the ETSAP website as *TIMESDoc-Intro.pdf*, and
- Chapter 6 of “Documentation for the TIMES Model – Part II” (authors Richard Loulou, Uwe Remme, Amit Kanudia, Antti Lehtila, Gary Goldstein), which can be downloaded from the ETSAP website as *TIMESDoc-Details.pdf*.

For a concrete example demonstrating Run Model using the TIMES Endogenous Technology Learning (ETL) Extension, see the non-BASE scenario **ETL** and the online Case **ETL** in database Example4-v661.mdb (distributed with ANSWER-TIMES version 6.6.1 and higher).

## Specification of Endogenous Technology Learning (ETL) Extension Data Parameters in ANSWER-TIMES

The TIMES Endogenous Technology Learning (ETL) Extension involves 6 Data Parameters, as follows:

ETL Data Parameter	Description
ETL-CCAP0	Initial cum. capacity (starting point on learning curve)
ETL-CCAPM	Maximum cum. capacity (ending point on learning curve)
ETL-PRAT	Progress ratio
ETL-SC0	Investment cost corresp. to starting point on learning curve
ETL-SEG	Number of segments for cumulative cost curve
ETL-TEG	Indicates process for which learning curve is specified

(In ANSWER-TIMES, the Data Parameter names used in the TIMES GAMS code are prefixed by “ETL-“.)

ETL Data Parameters may be specified on either the Process tab, or on the Parameter tab.

### Process Tab

On the Process tab, specify that ETL applies to a particular Process by selecting that Process and using the AddRow in the TID spread to add each of the above parameters. (Use of the AddRow in the TID spread suffices, since each of the 6 ETL Data Parameters is a TID parameter.)

- For the demonstration database Example4-v661.mdb, if you make the non-BASE scenario **ETL** the editable scenario, move to the Process tab and select process E41 (Natural gas combined-cycle plant), you will see that the 6 ETL TID Data Parameters have already been specified for process E41. See the screen snapshot on the following page.

Global | TimeSlice | Commodity | CommGroup | Process | TradeProcess | Constraint | Stochastic | Parameter

Items Filter:  Sets  Named \*All Processes (PRC)

Name	Region	Description	Status
E01	REG	Coal Steam Electric	
E21	REG	LWR Nuclear Plant	
E31	REG	Hydro-electric Plant	
E41	REG	Natural gas combined-cycle plant	M
E51	REG	Pumped Storage Power Plant	
E70	REG	Oil Plant	

Item Management: Current Process: E41

Subset Parameters: \*C Process, Specific

Scenario	Parameter	Region	Process	Commo	CommG	Comm	Item5	Item6	I/E	1990	2000	2010	201E
BASE	NCAP_CHPR	?	REG	E41	-	-	-	UP	0	0.9778	0.9778	0.9778	0.9
BASE	NCAP_COST	?	REG	E41	-	-	-	-	0	690.0000	690.0000	660.0000	660.0
M	ETL	NCAP_COST	?	REG	E41	-	-	-	0	0.0000	0.0000	0.0000	0.0
BASE	NCAP_FDM	?	REG	E41	-	-	-	-	0	35.0000	35.0000	33.0000	33.0
BASE	NCAP_TLIFE	?	REG	E41	-	-	-	-	0	35	35	35	

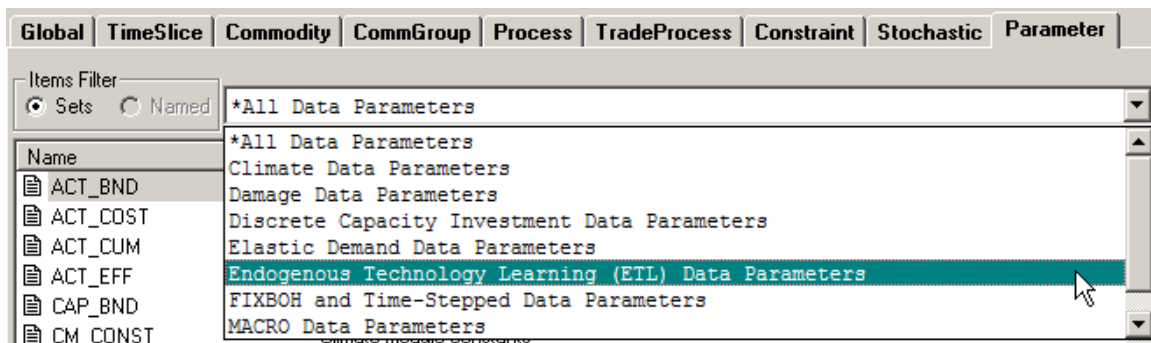
Add ETL

Scenario	Parameter	Region	Process	Commo	Item3	Year	Item5	Item6	Value
M	ETL	ETL-CCAP0	?	REG	E41	-	-	-	0.5000
M	ETL	ETL-CCAPM	?	REG	E41	-	-	-	4.0000
M	ETL	ETL-PRAT	?	REG	E41	-	-	-	0.9600
M	ETL	ETL-SC0	?	REG	E41	-	-	-	600.0000
M	ETL	ETL-SEG	?	REG	E41	-	-	-	6
M	ETL	ETL-TEG	?	REG	E41	-	-	-	1
BASE	NCAP_TLIFEp	?	REG	E41	-	-	-	1989	35







- Note that to avoid double-counting of costs for investment in new capacity for process E41, zero values for the NCAP\_COST parameter are specified for scenario ETL – these values will take precedence over the non-zero values for NCAP\_COST that are specified in the BASE scenario.

### Parameter Tab

The Parameter tab offers the convenience of being able to see all instances of ETL Data Parameters in the database (for the currently selected scenarios) and also provides a convenient way of adding these parameters for multiple Processes. On the Parameter tab, drop down the long combobox, and select the Endogenous Technology Learning (ETL) Data Parameters setting:



This provides the convenience of displaying just those Data Parameters that are specific to the TIMES Endogenous Technology Learning (ETL) Extension:

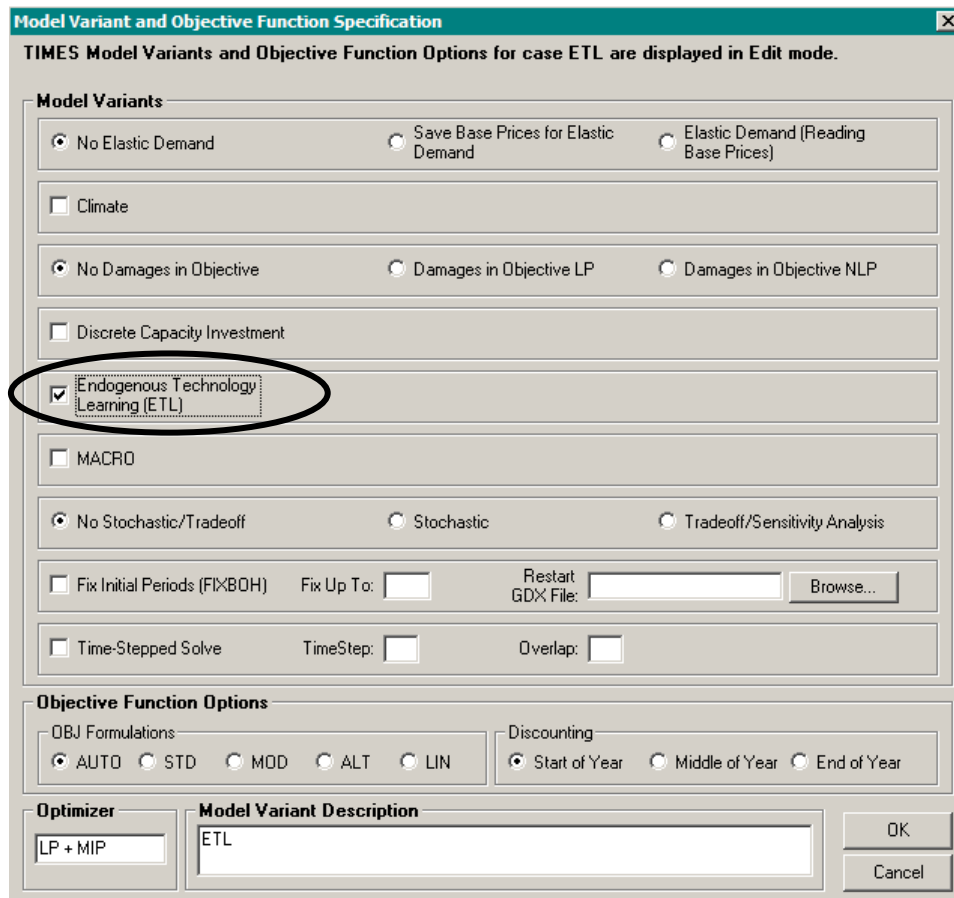
Global			TimeSlice			Commodity			CommGroup			Process			TradeProcess			Constraint			Stochastic			Parameter		
Items Filter																										
<input checked="" type="radio"/> Sets <input type="radio"/> Named <b>Endogenous Technology Learning (ETL) Data Parameters</b>																										
Name	Description																				Status					
 ETL-CCAP0	Initial cum. capacity (starting point on learning curve)																									
 ETL-CCAPM	Maximum cum. capacity (ending point on learning curve)																									
 ETL-PRAT	Progress ratio																									
 ETL-SC0	Investment cost corresp. to starting point on learning curve																									
 ETL-SEG	Number of segments for cumulative cost curve																									
 ETL-TEG	Indicates process for which learning curve is specified																									

Now use the AddRow facility to specify Endogenous Technology Learning (ETL) Data Parameter instances as needed.

### Specifying an Endogenous Technology Learning (ETL) Extension Model Run in ANSWER-TIMES

To specify in ANSWER-TIMES that a TIMES model run uses the Endogenous Technology Learning (ETL) Extension, click on the **Specify Model Variant...** button on the Run Model form, and then check the Endogenous Technology Learning (ETL) checkbox.

- For Run **ETL** as the current run on the Run Model form, this displays:



**Model Variant and Objective Function Specification**

TIMES Model Variants and Objective Function Options for case ETL are displayed in Edit mode.

**Model Variants**

No Elastic Demand     Save Base Prices for Elastic Demand     Elastic Demand (Reading Base Prices)

Climate

No Damages in Objective     Damages in Objective LP     Damages in Objective NLP

Discrete Capacity Investment

**Endogenous Technology Learning (ETL)**

MACRO

No Stochastic/Tradeoff     Stochastic     Tradeoff/Sensitivity Analysis

Fix Initial Periods (FIXBOH)    Fix Up To:     Restart GD&X File:     

Time-Stepped Solve    TimeStep:     Overlap:

**Objective Function Options**

OBJ Formulations:  AUTO     STD     MOD     ALT     LIN

Discounting:  Start of Year     Middle of Year     End of Year

**Optimizer**: LP + MIP

**Model Variant Description**: ETL

- Click on the [OK] button on the Model Variant Specification form to return to the Run Model form, and click on the [OK] button of the Run Model form to carry out Run Model using the Endogenous Technology Learning (ETL) Extension. Note that a MIP (Mixed Integer Programming) optimizer is needed to carry out an Endogenous Technology Learning (ETL) model run.
- ANSWER-TIMES then ensures that the control variable **ETL** is set to **YES** in the GEN file that controls the TIMES GAMS model run, by inserting:

**\$SET ETL 'YES'**

This can be seen by opening the file ETL.GEN with a text editor.

### **“Run Model” considerations for an (Endogenous Technology Learning) MIP Run**

The “Run Model” outline given above ignores important considerations that apply when carrying out any MIP Run for a MIP problem that has a large number of integer/binary variables.

One such consideration is to specify a value for the GAMS OPTCR parameter that controls a mixed integer programming run. The OPTCR parameter is a relative termination tolerance, meaning that the MIP solver will stop and report the first integer solution found that is within  $100 \times \text{OPTCR} \%$  of the best possible solution. That is, if OPTCR is set at 0.01, the MIP solver will stop when it obtains an integer solution that is within 1% of the best possible solution.

- If OPTCR is set at 0.0, the MIP solver will continue until it has found the optimal integer solution, and verified that this integer solution is indeed optimal. This may involve a prohibitive amount of time for a MIP problem that has a large number of integer/binary variables.

For additional details, see the GAMS Users Guide, and the documentation that is specific to the MIP optimizer that you are running.

#### Setting a Value for the OPTCR parameter in ANSWER-TIMES

In ANSWER-TIMES, you can set a value for the OPTCR parameter by intervening in the \*.GEN file that controls your MIP run. Near the bottom of the GEN file are the following 2 lines:

```
* Unasterisk the line below to set MIP optimality tolerance for an ETL/Lumpy
Investment run.
*OPTION OPTCR = 0.1;
```

All that you need to do is remove the asterisk from the second line and replace the value of 0.1 by your desired optimality tolerance, so for example to specify a value for OPTCR of 0.01 you would change the second line to become:

```
OPTION OPTCR = 0.01;
```

- If you want to do a succession of MIP runs with a particular value for OPTCR, then invoke menu option “Run, Edit GEN File Template” to make this change to your Template.GEN file. This will have the effect that the \*.GEN file for all subsequent model runs will specify this particular value for OPTCR. (For details of this facility, see section 6.1.5.1 ‘Run, Edit GEN File Template’ facility in the *ANSWERv6-TIMES User Manual.pdf*.)

- If you want to vary the value for OPTCR on a run by run basis, then before you click on the [OK] button on the Run Model form, you should check the Edit GAMS Control File checkbox at the bottom left of the Run Model form:

The image shows a dialog box with several checkboxes. The checkbox labeled 'Edit GAMS Control File' is checked and circled in black. Other checkboxes include 'Generate Files, Do Not Run', 'Regenerate Base DD File', 'Regenerate Non-Base DDS Files', 'Regenerate Rule-based DDSs', 'Create Results For Import into ANSWER', 'Suppress Pure Zero Time Series Results', 'Import Results Automatically', and 'Automatic Repair & Compact after Import'. At the bottom right are 'OK' and 'Cancel' buttons.

You will then be provided with the opportunity to edit the \*.GEN file for your current run, and hence to specify the value for OPTCR that you wish to apply for your current run. (For details see section 6.1.4.1 Run Model 'Edit GAMS Control File' checkbox option in the *ANSWERv6-TIMES User Manual.pdf*.)

- For the tiny Endogenous Technology Learning (ETL) MIP problem **ETL** above, a value for OPTCR of 0.0 was specified, so that the optimal integer solution was obtained.