TIMES Version 4.1 User Note
March 2017 (Updated April 2023)

Retrofits and Lifetime Extensions in TIMES

Introduction

Retrofitting and lifetime extension are frequently applied technical options for extending the operating lifetime or for improving the economic or environmental performance of existing real-world plants. After 20–25 years of operation, for many plants the strategic decision arises whether one should continue operating the old plant by investing into a refurbishment, or close down the old plant and build some brand-new capacity instead.

Retrofit and lifetime extension refurbishments may involve, for example:

- Equipping the plant with state-of-the-art boiler, turbine, or process control;
- Bio-conversion: modifying the plant for utilizing biomass as the main fuel, or as a co-firing fuel (may require investing into a new boiler or a gasifier);
- CCS retrofit: modify the plant for applying post-combustion carbon capture.

Starting from version 4.1.2, the TIMES model generator offers a simple dedicated facility supporting the modeling of retrofit (RF) and lifetime extension (LE) options. The main characteristics of the built-in facility can be summarized in the following way:

- Each host process, for which some RF/LE options are to be included, can be modeled to have any number of different RF/LE options;
- Each of the RF/LE options must be modeled in the same way as any new technologies (including the topology, process transformation parameters, availabilities, technical lifetime etc.);
- Whenever the model chooses to invest into a RF/LE option, the same amount of capacity of the host process will be simultaneously retired;
- The investment costs for the RF/LE options should include only the additional investments for the refurbishment in question;
- Fixed and variable O&M costs must cover full costs during the RF/LE operation.

Due to possible changes in all operational parameters, the refurbishment options are thus modeled by distinct technologies that have a full process characterization. There is at least the following notable limitation in the TIMES implementation:

- Each RF/LE option can only be applied to a single host process.

TIMES attributes

There is only a single new TIMES attribute needed for the modeling of RF/LE options:

- PRC_REFIT(reg,prc,p)
  Mapping of host process prc to a retrofit or lifetime extension option p in region reg. The attribute is a parameter, the value of which determines the type of the refurbishment option as follows:
  - PRC_REFIT(reg,prc,p) = ±1 mod 2 : The technology p is a lifetime extension option (+1) or a retrofit option (–1);
  - If all the values ±N are such that $\forall p$:(Abs(±N) > 2), or the value of +2 or +4 is specified also for the host process prc, the refitted capacity of the host process prc is forced to be equal to the retired capacity in each period.
  - If the value of +4 is specified for the host process prc, cascading of forced retrofit investments are disabled for each vintage of the host process

The differences between a retrofit (RF) option and a lifetime extension (LE) option, when modeled by using the PRC_REFIT parameter, can be characterized as follows:

- Investing into a retrofit option will never extend the original lifetime of the host process, but investing into a lifetime extension option will extend its lifetime in accordance with the full technical lifetime of the LE option.
- Retrofit options never have any salvage value, but lifetime extension options will have a salvage value whenever the lifetime of the LE option would extend beyond the model horizon, and is accounted according to the standard salvage value accounting in TIMES.

Whenever the model chooses to invest into either a retrofit or a lifetime extension option, the same amount of capacity of the host process will be simultaneously retired. The new capacity of the RF/LE option thus fully replaces the corresponding amount of the old plant capacity. The retired old capacity will not have any fixed or variable costs after its retirement, nor any salvage value (but will retain its decommissioning costs or scrap value, if defined).

Using the PRC_REFIT parameter requires that early retirements are allowed in the model. The user should thus make sure that one of the following TIMES switches is used:

- $SET RETIRE LP
- $SET RETIRE MIP
- $SET DSCAUTO YES

Equation formulation

When retirements are enabled, the TIMES model generator will generate the following equations according to the user-defined PRC_REFIT parameters:

$$
\begin{aligned}
&EQL\_REFIT_{r,tt,t,prc} \quad \ni \left\{\exists p : \left(PRC\_REFIT_{r,prc,p} <> 0 \wedge RTP\_CPTYR_{r,tt,t,p}\right)\right\} \\
&\sum_{p \in RTP\_CPTYR_{r,tt,t,p}} COEF\_CPT_{r,tt,t,p} \times \left(VAR\_NCAP_{r,tt,p} - VAR\_SCAP_{r,tt,t,p}\right) \times \\
&\max\left(DIAG(tt,t), -SIGN(PRC\_REFIT(r,prc,p))\right) \qquad (1) \\
&\leq / = \\
&\sum_{v \in RTP\_CPTYR_{r,v,tt,prc}} COEF\_CPT_{r,v,t,prc} \times \left(VAR\_SCAP_{r,v,tt,prc} - VAR\_SCAP_{r,v,tt-1,prc}\right)
\end{aligned}
$$

where

- $RTP\_CPTYR_{r,v,t,p}$ is the TIMES capacity transfer mapping set
- $COEF\_CPT_{r,v,t,p}$ is the TIMES capacity transfer coefficient parameter
- DIAG(tt,t) is the GAMS DIAG function, returning 1 iff tt=t
- SIGN(x) is the GAMS SIGN function returning ±1 or 0, according to the sign of x
- $VAR\_NCAP_{r,v,p}$ is the TIMES new capacity variable
- $VAR\_SCAP_{r,v,t,p}$ is the TIMES cumulative retirement variable

References:

Loulou, R., Lehtilä, A., Kanudia, A., Remme, U. & Goldstein, G. 2016. Documentation for the TIMES Model, Part II. Energy Technology Systems Analysis Programme.