

## Levelized cost calculation from TIMES results

A levelized cost calculation looks to weight all the costs influencing the choice of a technology by TIMES. It takes into consideration investment, operating, fuel, and other costs as a means of comparing the full cost associated with each technology.

Levelized cost can be calculated according to the following general formula:

$$LEC = \frac{\sum_{t=1}^n \frac{IC_t}{(1+r)^{t-1}} + \frac{OC_t + VC_t + \sum_i FC_{i,t} + FD_{i,t} + \sum_j ED_{j,t} - \sum_k BD_{k,t}}{(1+r)^{t-0.5}}}{\sum_{t=1}^n \frac{\sum_m MO_{m,t}}{(1+r)^{t-0.5}}} \quad (1)$$

where

- $r$  = discount rate (e.g. 5%)
- $IC_t$  = investment expenditure in (the beginning of) year  $t$
- $OC_t$  = fixed operating expenditure in year  $t$
- $VC_t$  = variable operating expenditure in year  $t$
- $FC_{it}$  = fuel-specific operating expenditure for fuel  $i$  in year  $t$
- $FD_{it}$  = fuel-specific acquisition expenditure for fuel  $i$  in year  $t$
- $ED_{jt}$  = emission-specific allowance expenditure for emission  $j$  in year  $t$  (optional)
- $BD_{kt}$  = revenues from by-product  $k$  in year  $t$  (optional; see below)
- $MO_{mt}$  = output of main product  $m$  in year  $t$

The exponent  $t-0.5$  in the formula indicates the good practice of using mid-year discounting for continuous streams of annual expenditures.

In TIMES, the specific investment, fixed and variable O&M costs and fuel-specific flow costs are calculated directly from the input data. However, for the fuel acquisition prices, emission prices and by-product prices, **commodity marginals** from the model solution are used. All the unit costs are multiplied by the corresponding **variable levels** as given by the model solution: investment cost and fixed operating costs are multiplied by the amounts of capacity installed / existing, variable operation costs by the activity levels, and fuel-specific costs by the process flow levels. Mid-year discounting can also be activated.

The outputs of the main products are taken from the flow levels of the commodities in the primary group (PG) of the process. An exception is CHP processes, for which the electricity output is considered the sole main output, and heat is considered as a by-product.

### Options for reporting variants:

1. Do not include emission prices or by-product revenues in the calculation (RPT\_OPT('NCAP','1') = -1):

In this option emission prices are omitted from the calculation, in accordance with the most commonly used convention for LEC calculation. Consequently, any by-product revenues need to be omitted as well, because if emissions have prices, the by-product prices in the solution would of course be polluted by those prices, and thus it would be inconsistent to use them in the calculation. Instead, in this case any amount of by-product energy produced by ELE, CHP and HPL processes is

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indirectly credited by reducing the fuel-specific costs in the calculation to the fraction of the main output in the total amount of energy produced. This approach of crediting for by-products in the LEC calculation has been utilized, for example, in CHP systems studies in the University of Chicago (see e.g. Kalam et al. 2009).

### 2. Include both emission prices and by-product revenues in the calculation

(RPT\_OPT('NCAP','1') = 1):

In this option both emission prices and by-product revenues are included in the calculation. The levelized cost thus represents the unit cost after subtracting the levelized value of all by-products from the gross value of the levelized cost. This approach of crediting for by-products in the LEC calculation has been utilized, for example, by the IEA (see IEA 2010).

### 3. Include not only emission prices and by-product revenues, but also the revenues from the main product in the calculation (RPT\_OPT('NCAP','1') = 2):

This option is similar to option (2) above, but in this case all product revenues are included in the calculation, including also the peak capacity credit from the TIMES peaking equation (when defined). The calculated LEC value thus represents the levelized **net** unit cost after subtracting the value of all products from the gross levelized cost. For competitive new capacity vintages, the resulting levelized cost should in this case generally be **negative**, because investments into technologies that enter the solution are normally profitable. For the marginal technologies the levelized cost can be expected to be very close to zero. Only those technologies that have been in some way forced into the solution, e.g. by specifying lower bounds on the capacity or by some other types of constraints, should normally have a positive levelized cost when using this option.

In the TIMES calculation, the expenditures for technology investments and process commodity flows include also taxes minus subsidies, if such have been specified.

The levelized cost results are stored in the VEDA-BE **Var\_NcapR** result attribute, with the qualifier "LEV COST" (with a possible system label prefix).

### Recommended TIMES Control options:

\$	SET OBJ	AUTO	
\$	SET OBLONG	YES	
\$	SET MID_YEAR	YES	
\$	SET RPT_OPT	NCAP.1 -1	(option 1 above)
\$	SET RPT_OPT	NCAP.1 1	(option 2 above)
\$	SET RPT_OPT	NCAP.1 2	(option 3 above)

### References:

IEA 2010. *Projected Costs of Generating Electricity – 2010 Edition*. Paris: OECD, International Energy Agency. <http://www.oecd-nea.org/pub/egc/>

Kalam, Adil, King, Abigail, Moret, Ellen & Weerasinghe, Upekha 2009. *Combined Heat and Power Systems: Identifying Economic and Policy Barriers to Growth*. University of Illinois Chicago. <http://humanities.uchicago.edu/orgs/institute/bigproblems/Team5-1209.pdf>