LCOH for Solar Thermal Applications

INFO Sheet A.2

Description:	*Guideline for levelized cost of heat (LCOH) calculations for solar thermal applications*
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Authors:	Yoann Louvet, University of Kassel; Stephan Fischer, ITW Stuttgart; Simon Furbo, Technical University of Denmark; Federico Giovanetti, ISFH; Franz Mauthner, AEE Intec; Daniel Mugnier, Tecsol; Daniel Philippen, SPF
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Introduction

In the framework of the IEA-SHC Task 54 appeared the need of assessing the costs of the heat produced by solar thermal systems over their life time in order to compare different designs and technological solutions with one another. The levelized cost of heat (LCOH), a measure based on the concept of levelized cost of energy, widespread in the electrical power sector, was chosen. This info sheet builds on the work of the FRoNT project [1] who laid the foundations for the application of the method to any heating technology. It aims at detailing the methodology to calculate the levelized cost of the heat substituted by solar thermal energy. Furthermore, an extension of the concept is suggested in order to estimate the cost of the heat generated by the entire solar assisted heating system, or the conventional sources of heat supply.

General formulation

The LCOH for solar thermal applications can be derived from the following formula, based on [1] and [2]:

$$LCOH = \frac{I_0 - S_0 + \sum_{t=1}^{T} \frac{C_t(1-TR) - DEP_t \cdot TR}{(1+r)^t} - \frac{RV}{(1+r)^T}}{\sum_{t=1}^{T} \frac{E_t}{(1+r)^t}}$$

Where:

$LCOH$: levelized cost of heat in €/kWh
I_0: initial investment in €
S_0: subsidies and incentives in €
C_t: operation and maintenance costs (year t) in €
TR: corporate tax rate in %
DEP_t: asset depreciation (year t) in €
RV: residual value in €
E_t: saved final energy (year t) in kWh
r: discount rate in %
T: period of analysis in year

Notes: 1) It is possible to input the cost variables C_t, DEP_t and RV either in current or in constant euros. The discount rate should be chosen accordingly, respectively nominal or real (adjusted for inflation). As a consequence one might obtain two different LCOH values, depending on the discount rate selected: the LCOH in nominal terms and the LCOH in real terms. By definition, the LCOH in nominal terms is always larger than the one in real terms (as $r_{nominal} > r_{real}$).

2) All costs are net costs (excluding VAT).

Conventional reference system

The calculation of the LCOH substituted by solar thermal energy requires the definition of a conventional reference heating system. This conventional reference system is a theoretical heating system which would supply the same amount of energy to the end user as the solar thermal system, but without solar assistance. It is needed to calculate I_0 and E_t (see below).

Main assumptions for solar thermal applications

This section focuses on the LCOH substituted by solar thermal energy. All cost variables (I_0, S_0, C_t, DEP_t and RV) thus only refer to the components dedicated to solar thermal heat production and integration, mainly collectors, buffer store, pumps, heat exchangers, pipe works and control unit.

- Initial investment (I_0):
  - The cost of the storage from the conventional reference system and the associated installation costs should be subtracted from I_0 if applicable.
  - In case of building integrated solar thermal systems both for new buildings or building renovation, the cost of the building component (roof or wall section) substituted with solar thermal collectors and the associated installation costs should be subtracted from I_0 if applicable.
  - The size of the storage in the conventional reference system strongly depends on the application. Some guidelines might be used, as [3] for domestic hot water systems for instance.
- Subsidies and incentives (S_0):
  - The user might decide to include or not subsidies and other incentives in the calculation.
- Operation and maintenance costs (C_t):
  - $C_t = O_t + M_t$ where O_t and M_t respectively corresponds to the operation and maintenance costs.
  - It is recommended to use a single fixed value for O_t and M_t (O and M):

$$C_t = O + M$$

  - Operation costs (O) correspond to the power consumption of the pump and controller and depend on the electricity price, different from country to country. The running time of the pump can only be determined with numerical simulations.
  - For refined calculations, it is possible to apply an electricity price index increase different from the inflation. In this case it is necessary to adjust the index for inflation if the cost variables are given in constant euros.
  - Usually $0.01 \cdot I_0 < M < 0.02 \cdot I_0$ [4]. For a more detailed analysis, the values given in [5] might also be used.
- Corporate tax rate (TR) and asset depreciation (DEP_t):
  - Only apply to the industrial and commercial sectors. For the residential sector one should take $TR = DEP_t = 0$.

- Residual value (RV):
  - For residential solar thermal applications, the residual value is considered equal to zero: $RV = 0$. For the industrial and commercial sectors however positive values might be used.
  - To calculate RV, one should compare the period of analysis (T) and the technical lifetime of the different components. Each component having a different technical lifetime, its replacement should be taken into consideration when calculating RV. Typical values for assessing the technical lifetime of components might be found in [5] and [6].
- Saved final energy (E_t):
  - To allow the comparison between different solar thermal technologies and system designs for a given reference case, the saved final energy should be used here and not the solar energy yield.
  - Following [3], $E_t = E_{conv} - E_{aux} = \frac{Q_{conv,net}}{\eta_{conv}} - \frac{Q_{aux,net}}{\eta_{aux}} = \frac{Q_d + Q_{l,conv}}{\eta_{conv}} - \frac{Q_{aux,net}}{\eta_{aux}}$

    Where:

E_{conv} : gross (final) energy demand of the conventional (reference) heating system in kWh
E_{aux}: gross (final) auxiliary energy demand of the solar heating system in kWh
$Q_{conv,net}$: net energy demand of the conventional heating system in kWh
$Q_{aux,net}$: net energy demand of the solar heating system delivered by the auxiliary heater in kWh
Q_d: total heat demand in kWh
$Q_{l,conv}$: heat losses of the heat storage of the conventional (reference) heating system in kWh
η_{conv}: annual utilisation ratio[1] of the heater of the conventional (reference) heating system
η_{aux}: annual utilisation ratio of the auxiliary heater of the solar heating system

  - η_{conv} and η_{aux} are highly dependent on the type of heater and on the operating conditions (notably winter vs. summer mode). However for practical reasons, $\eta_{conv} = \eta_{aux}$ as well as a single yearly value should be considered. Values for η_{conv} = η_{aux} will be fixed within the reference solar thermal systems defined in Task 54. They will depend on the country and the kind of reference heating system used.
  - Following these assumptions:

$$E_t = \frac{Q_d + Q_{l,conv} - Q_{aux,net}}{\eta_{conv}}$$

  - Q_d and $Q_{aux,net}$ might be determined with a single simulation of the solar thermal system. $Q_{l,conv}$ might be estimated either theoretically, for instance according to [3], or by means of a second simulation where the solar thermal loop is turned off. In the latter case, one should not forget to adapt the size of the heat storage.
  - Simulations normally always estimate E_1. A correction factor might be applied to the subsequent E_t ($t = [2..T]$) in order to take into consideration the ageing of the system.

[1] The annual utilisation ratio takes into consideration the steady-state efficiency of the heater as well as cyclic effect during transient phases and standby losses. Indicative values are given in [4] and [7] for instance.

Unfortunately, only few analyses are available on the degradation rate of solar thermal systems. Experience shows however that each system should be considered specifically as there is so far no general criterion applying to this issue.

- Discount rate (r):
  - The discount rate is normally taken equal to the weighted average cost of capital (WACC). For single-family house systems, the total system costs are usually paid up front. In this case, $r = 0$ (real discount rate).
  - The nominal discount rate is derived from the real one with the relationship $r_{nominal} = r_{real} \cdot (1 + i) + i$, where i is the inflation rate.
- Period of analysis (T):
  - It is usually equal to the expected technical lifetime of the solar thermal system. This value is country and system dependent. For domestic systems for instance, 20 to 25 years in Germany and 25 years in Switzerland are commonly considered. In Denmark, 30 to 35 years are standard for large solar heating plants.
  - One could also choose to consider the economic lifetime (expected period over which the asset will yield benefits) rather than the technical lifetime.

LCOH substituted by solar thermal energy vs. LCOH generated by the solar assisted heating system

The methodology described in the previous section allows the calculation of the levelized cost of the heat which is substituted by solar energy. A similar approach was previously applied in [8] and [9]. This is sufficient to compare different solar thermal technologies and system designs against each other. However in order to compare a solar assisted heating system with other heating technologies (heat pump, wood pellets boiler, etc.) the levelized cost of the total heat generated by the solar assisted heating system has to be calculated. To do so the methodology described above for the calculation of each term of the LCOH equation has to be adapted as described in Table 1.

Table 1. Assumptions for the calculations of the different terms of the LCOH equation depending on the type of LCOH considered.

Parameter	LCOH substituted by solar thermal energy	LCOH generated by the solar assisted heating system
I_0	Investment costs for the "solar related components" of the entire heating system	Investment costs for the entire heating system
C_t	O&M costs related to the "solar related components" of the entire heating system	O&M costs for the entire heating system; the costs of the fuel used by the auxiliary heater need to be integrated here
DEP_t	Depreciation of the "solar related components" of the entire heating system	Depreciation of the entire heating system
S_0	Subsidies for the "solar related components" of the entire heating system	All subsidies given to build the entire heating system
RV	Residual value of the "solar related components" of the entire heating system	Residual value of the entire heating system
E_t	Saved final energy	Total heat demand

References

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