Description:	*Reduction of maintenance costs for solar thermal systems with overheating prevention*
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Authors:	Bert Schiebler (ISFH Hameln), Federico Giovannetti (ISFH Hameln), Stephan Fischer (IGTE Stuttgart)
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Introduction

After sale costs of solar thermal systems represent a significant part of the overall costs of the delivered solar heat. In practice, high stagnation loads have a strong impact on the maintenance efforts, which impair the cost-efficiency and generally the attractiveness of solar thermal installations. To prevent high temperature loads in solar circuits, different approaches are usually pursued. Most of them are based on additional cooling systems or collector draining strategies (drain back), which require more complex hydraulic installations and control technologies respectively. Other approaches avoid overheating directly in the collector, e.g. with heat pipes [1] [2], thermochromic absorber coatings [3], thermal actuated valves [4] or other technologies, which increase the thermal losses of the collector at high temperatures. In case of stagnation the maximum temperature in solar circuits using such collectors can be limited (see Figure 1) and the vapour formation can be reduced or even completely avoided. Thus, the thermomechanical stress of several components is significantly lower compared to systems with common collectors and this can lead to more reliable solar circuits. Within the scope of this report we evaluate the economic benefits of solar thermal systems with overheating prevention. The focus is on a possible reduction of maintenance costs in consideration of a significant limitation of the maximum temperature to 100 - 125°C and the complete avoidance of vapour formation in the solar circuit.

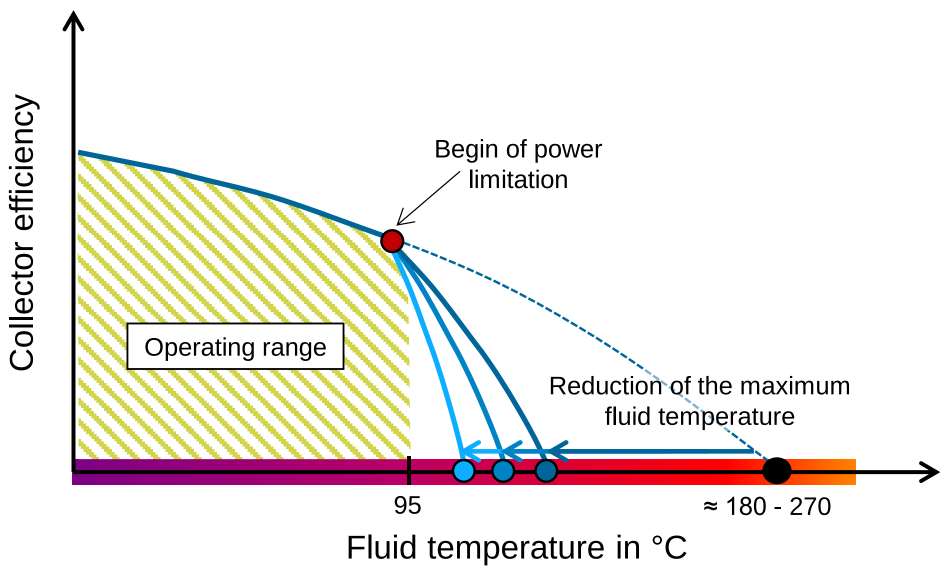
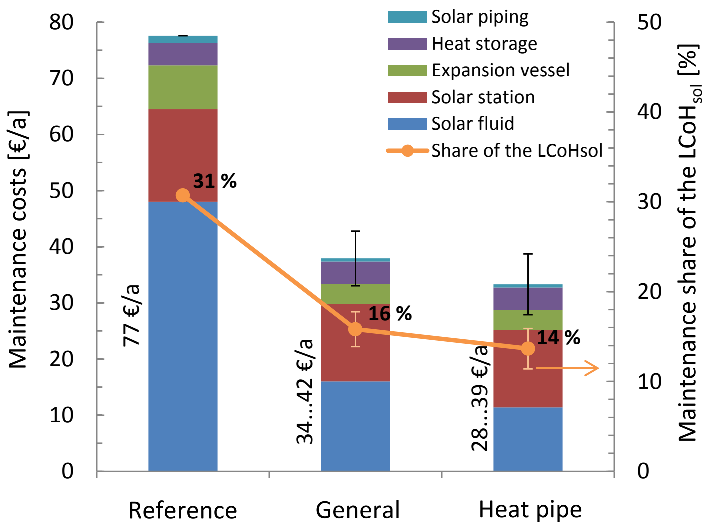


Figure 1: Exemplary efficiency curve of a solar collector with overheating prevention

Maintenance of solar thermal systems with overheating prevention

The maintenance costs are determined for a typical solar domestic hot water system (SDHW) with flat plate collectors according to the IEA TASK 54 German reference system [5]. Thus, the benefits of the temperature limitation can be easily assessed in relation to the costs of the reference system. An optimized system with overheating prevention offers a significantly higher operational safety as well as the extension of service intervals in general. Also the lifetime of several hydraulic components is increased as a consequence of lower thermomechanical stress. The following considerations are done for two types of optimizations. In the first case the maintenance costs are estimated for a "general" optimized system, where typical stagnation loads are avoided (no vapour) independently of a specific technology. In the second case the maintenance costs are investigated for a "heat pipe" system as concrete approach for temperature limitation. In addition to the general option further advantages, e.g. the smaller amount of solar fluid and their easier replacement procedure are considered. Representing these benefits with reliable figures is quite difficult. Our assumptions are based on information provided by manufacturers and installers and conveniently chosen to show a range of possible cost reductions. The overall maintenance costs of the reference system are defined in [5] and amount to 77 €/a. For a better understanding of the cost drivers we determine the maintenance costs for each relevant component in accordance to the routine suggested by the German guideline VDI 2067 [6]. Figure 2 shows the results of both considered system configurations.



Annual maintenance costs (no vapour, temperature limitation)	General system	Heat pipe system
Solar fluid	16 ± 0 €/a	11 ± 1 €/a
Solar station (solar pump, controller, etc.)	14 ± 3 €/a	14 ± 3 €/a
Expansion vessel	4 ± 1 €/a	4 ± 1 €/a
Heat storage	4 ± 0 €/a	4 ± 0 €/a
Solar piping	1 ± 0 €/a	1 ± 0 €/a
Total maintenance	**39 ± 4 €/a**	**34 ± 5 €/a**

Figure 2: Annual maintenance costs of both optimized systems (general and heat pipe) compared to the reference system as well as their share of the Levelized Cost of Heat (LCoH$_{sol,fin}$)

Maintaining the solar fluid is the most relevant cost driver. The lifetime of the water-glycol mixture depends on the intensity of the stagnation loads and typically amounts to about 5 – 7 years. According to the producer (Tyforop GmbH) its lifetime can be well beyond 10 years, if the maximum temperature is limited to about 125 °C and vaporization is completely avoided. Considering a system lifetime of 25 years we estimate, that the solar fluid is replaced three times in the reference system and one time in the system with overheating prevention. For the changing procedure of the solar fluid we calculate the costs of the fluid itself and the costs for the installer. For the heat pipe system we also take into account the easier filling and flushing procedure of heat pipe collectors, which is estimated in 1 – 2 h working hours. As a result, the annual costs for maintaining the solar fluid can be significantly reduced to 16 €/a (general system) and 11 €/a (heat pipe system). The maintenance effort of other components, such as the solar station or the expansion vessel depends only on their individual investment costs and their lifetime with regard to the mentioned VDI-2067 routine [6]. For example, the lifetime of the solar pump and of the expansion vessel is set to 10 and 15 years respectively. On the basis of this assumption, the expansion vessel features the highest potential for cost reduction after the solar fluid, due to the significantly smaller investment costs compared to the reference system, as shown in Figure 2.

Summarizing, as a consequence of the significant temperature limitation as well as the suppression of vapour formation the overall maintenance costs can be reduced from 77 €/a (reference system) to 39 €/a (general system). Under consideration of additional benefits by using heat pipe collectors the average maintenance costs can further decrease to 34 €/a. The share of the Levelized Cost of Solar Heat ($LCoH_{sol,fin}$) is correspondently shifted from 31 % (reference system) down to 14 %[1] (heat pipe system) as displayed in Figure 2.

[1] Referred to investment costs (I_0 = 3850 €), electricity costs (20 €/a) and saved final energy (E_t = 2226 kWh/a) of the reference system [5]

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