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Eidgenössisches Departement für
Umwelt, Verkehr, Energie und Kommunikation UVEK

Bundesamt für Energie BFE
Energieforschung

Final report of 30.11.2023

HP-Source

Integration options of heat sources

Executive Summary

Source: © Lägern Wohnen

Date: 30.11.2023

Site: Rapperswil

Subsidising party:
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SFOE-Contract number: SI/502144-01

The contents and the conclusions are the sole responsibility of the authors of this report.

Executive summary

The SFOE project WP-Source has the primary objective of alleviating restrictions on the heat source side in the higher capacity range from 50 kW on and enabling monovalent heat pump operation even where the boundary conditions make monovalent operation with an individual heat source impossible. For this purpose, combinations of heat sources were considered in order to overcome the limitations of individual heat sources. There are only a few examples of multi-source applications on the market and in the literature to date. The most common is the combination in the context of ground source regeneration, which is now being used more frequently, especially as solar regeneration. Depending on the boundary conditions, there is also potential for increasing efficiency and reducing costs through synergies between the heat sources.

Various strategies were considered for combining the heat sources, focusing on the heat sources air and ground, which are most frequently used in Switzerland.

- Peak load coverage of the primary air heat source by the secondary ground source
- Regeneration of the primary heat source ground with the secondary heat source air and sole operation of the air heat source
- Preheating of the primary heat source air by the secondary heat source exhaust air
- Utilization of a second heat source air in addition to a base load source wastewater, which contributes a constant share to the heat requirement throughout the year

The investigation was carried out using dynamic simulation for a new building with a high proportion of hot water heat demand of 66% and an existing building with a dominant heating demand of 80% in order to characterise the differences. The investigation revealed that the highest potential lies in the first two strategies, which is why these were focussed on.

Results of the Strategy “Peak load coverage”

For the strategy “peak load coverage with ground probes”, there are advantages in combination with capacity limitations of the primary heat source, as they can exist with the outdoor air heat source due to noise emissions. On the other hand, with a ground source only system, there may be space restrictions for the installation of a sufficient number of probes. Figure 1 shows the relative probe length compared to a 100% ground probe heat source for the parameter variations carried out. Due to the peak load coverage, both air and ground sources can be designed smaller, e.g. to 50% of the required source capacity, which alleviates noise as well as space and drilling depth restrictions.

Most variations show a robust behaviour, which simplifies the design for different boundary conditions. The biggest difference is in the probe arrangement between a line and compact field. The latter shows a higher degressive behaviour, as the natural regeneration is limited by the mutual influence of the probes (field effect) and a reduction in the length/number of probes and a lower load in the peak load case has a higher impact.

With the combination of air as the primary source and ground for sole peak load operation, significantly less energy is extracted from the ground than with a ground source only. As a result, the total installed probe length can be reduced disproportionately, which further helps to overcome restrictions that exist in particular in existing buildings. In the case of compact borehole heat exchanger fields, the reduction in probe length corresponds approximately to the energy extraction from the field, e.g. approx. 20% of the total source energy when designed for 50% of the total heating capacity. The simulation results also confirm efficiency advantages through better source temperatures and economic benefits.

In the simulations, the annual coefficient of performance can be increased from just under 3 (air source only) to 4.5 (ground probes only) depending on the proportion of capacity by the ground probe. The differences between new and existing buildings are relatively small, as the lower heating temperatures in the new building are compensated for by the higher proportion of domestic hot water.

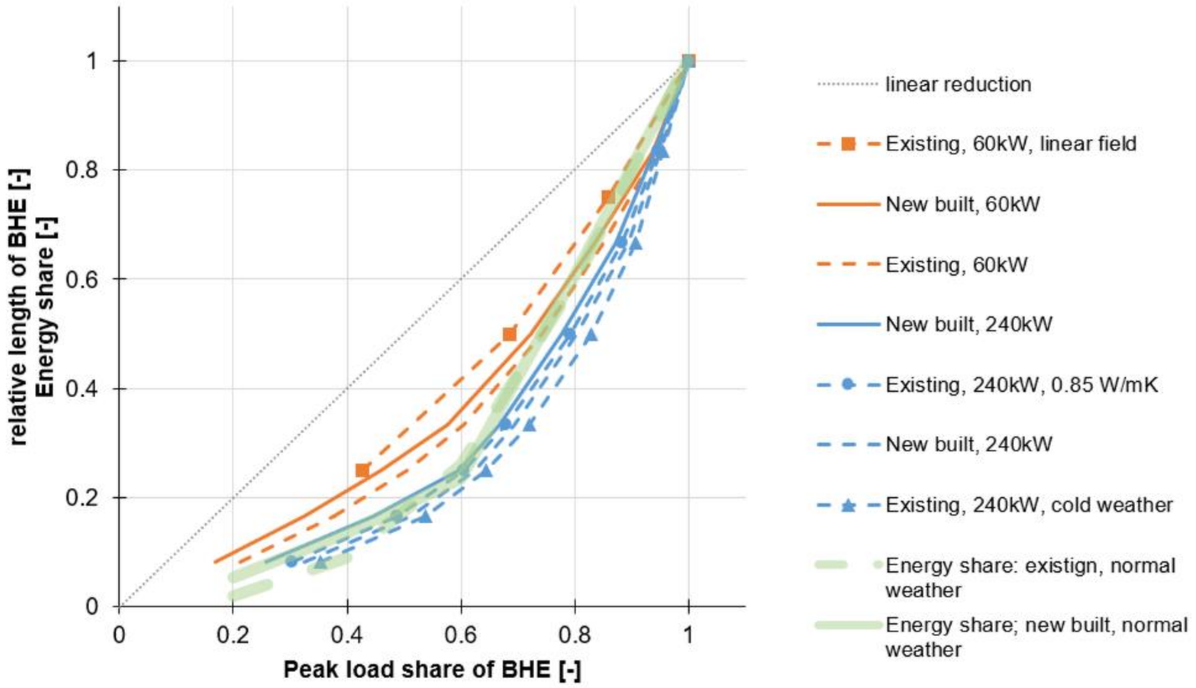

Figure 1: Parameter variations for the Strategy "Peak load coverage"

Figure 2 shows the cost structure for an existing building depending on the proportion of capacity by the ground probes and in comparison to a bivalent solution with natural gas for the market situation in June 2022. For the heat pump solutions, there are advantages of the individual sources for lower capacities of 60 kW. However, the additional costs for a heat pump solution are moderate at 50 CHF/kW and may enable the use of a monovalent heat pump. At higher outputs, the cost advantages of individual sources are reduced or even higher. Under these cost and tariff conditions, the specific costs of the monovalent solution with heat pump alone are even lower than peak coverage with natural gas. In new buildings, there is additional cooling potential by the ground probes compared to an air source-only.

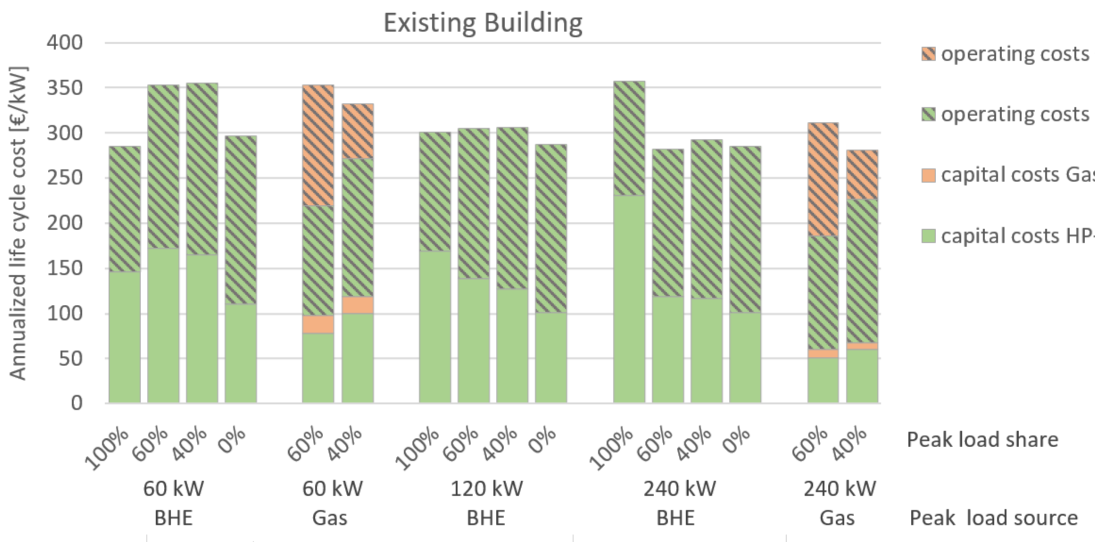

Figure 2: Economic evaluation of the concepts "Peak load coverage"

Results of the strategy Regeneration

The evaluation was primarily carried out with regard to the required area and drilling depth as a trade-off between cost and degree of regeneration. With regeneration, the probes can be arranged closer together, which opens up options for more probes on less space. For regeneration, solar absorbers, PV/T collectors and outdoor air heat exchangers were systematically analysed in parameter variations for different building sizes, probe field sizes, drilling depths, probe spacing and probe arrangements in the field. The results show that regeneration achieves economic benefits by reducing the required probe length, thus avoiding space and drilling depth restrictions.

In many cases, the cost savings can refinance or even overcompensate for the investment costs of the regeneration source. In the case of solar regeneration, for example, a cost-optimised design can be achieved as a ratio between collector area and saved probe length.
The cost-optimised degree of regeneration was in the range of 60-80% with different parameter variations. It was also confirmed that the effectiveness of regeneration increases with larger fields and smaller probe spacing.
Based on the results, a new diagram was developed which shows the necessity and cost-effectiveness of regeneration for a given heating capacity requirement and space conditions (site area, drilling depth) as well as the cost parameters, as shown in Figure 3 on the left.

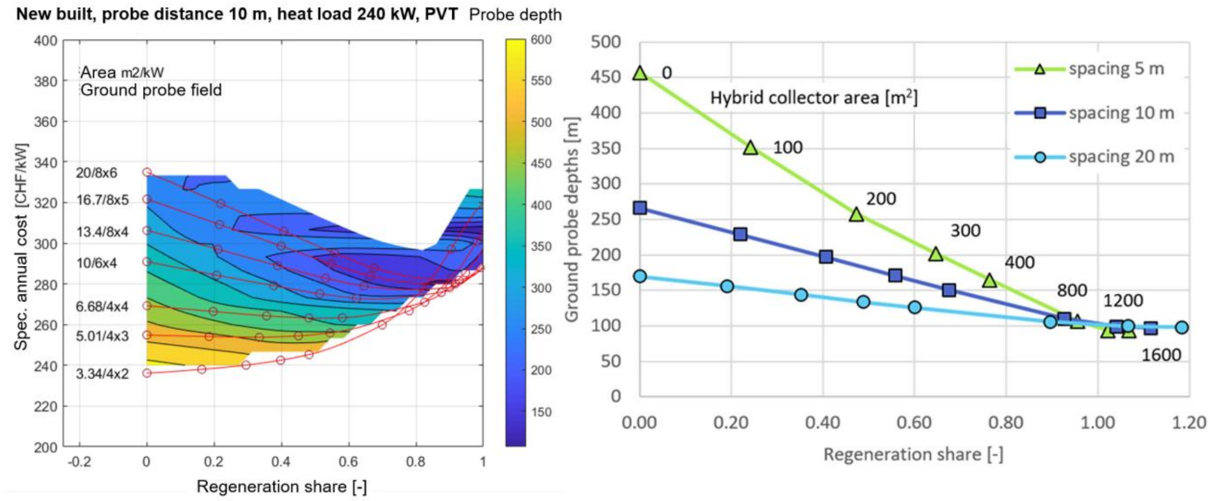

Figure 3: Annual cost dependent on the degree of regeneration (left) and required drilling depth (right)

The degree of regeneration on the x-axis can also be interpreted as a distribution between two sources, which means that this visualisation can also be used for other systems such as peak load coverage. Figure 3 on the right illustrates the required borehole depth depending on the probe spacing and degree of regeneration. If sufficient space is available, the system can be designed without regeneration and with a shallower borehole depth. However, space or drilling depth restrictions can be overcome as the degree of regeneration increases, with regeneration becoming more effective in limited spaces. Figure 4 shows the specific annual costs of different system variants with and without regeneration. From regeneration levels of 60-80%, there are no major changes, but the required regeneration area and the costs of the PV/T collectors increase sharply.

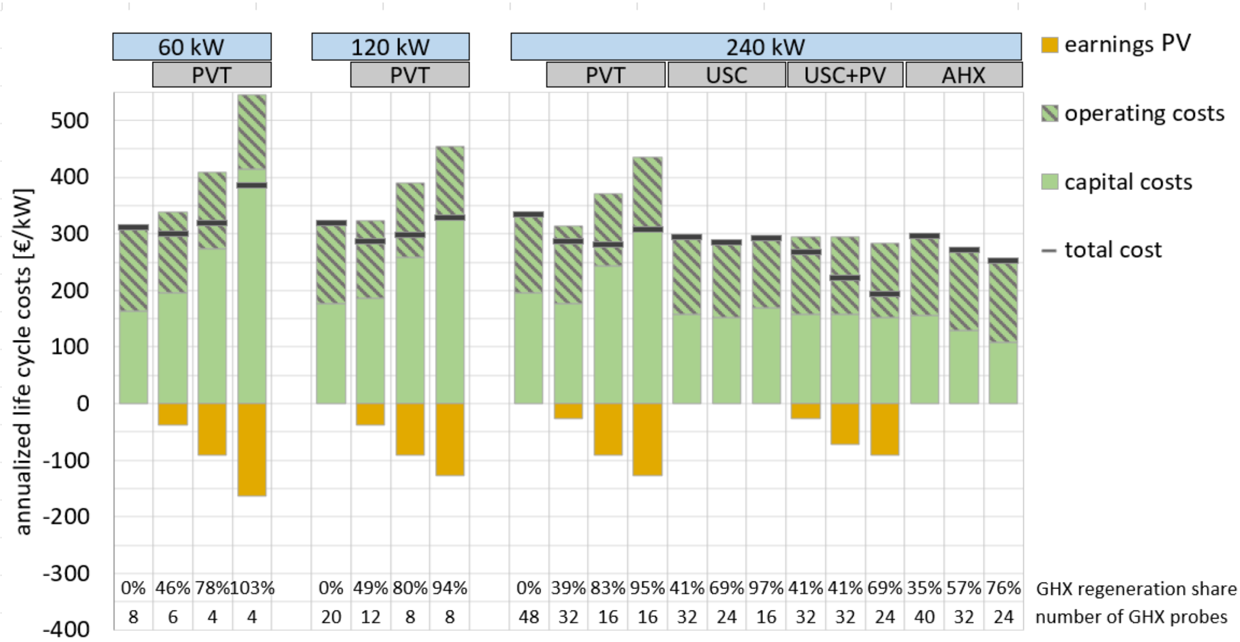

Figure 4: Economic evaluation of regeneration. For the USK + PV variant, the same roof area was used as for the PV/T variant, but the roof area that is not used for the USK was covered with PV

In this evaluation, the lowest costs are achieved with the uncovered solar collector (USK) combined with PV, although the considered systems do not differ much. The economic superiority of individual solutions is also strongly influenced by the cost parameters (drilling costs, tariff structure, system costs, interest rate, etc.).

Combination of Strategies

For higher outputs, a combination of the two strategies ‘regeneration’ and ‘peak load coverage’ may also be suitable. As the number of probes is already significantly reduced by peak load coverage, but the effectiveness of regeneration decreases with fewer probes, the combination only makes sense for higher capacities. Regeneration ensures slightly higher operating performance and additional robustness of the design. Figure 5 shows the annual costs for the analysed system with 240 kW heat output and 160 m deep probes.

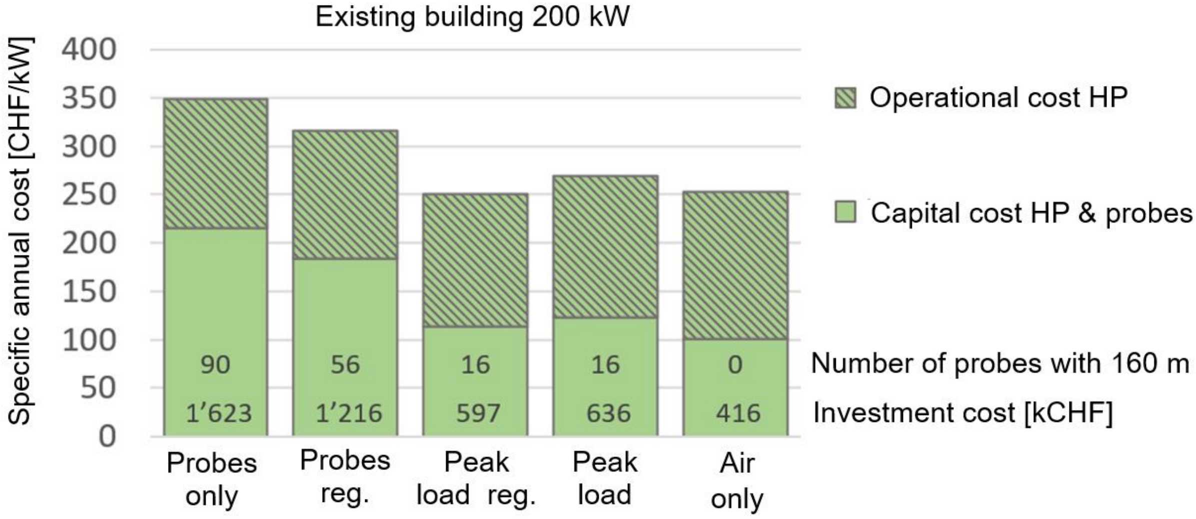

Figure 5: Annual cost for the system with 240 kW and 160 m probe length

Due to the lower power shares by the ground in the peak load concept, the efficiency increases are not very pronounced. Monitoring of the probe inlet temperature is necessary to prevent subcooling. With controlled return admixture, the probe inlet temperature is stabilised even at cold outlet temperatures from the heat pump. The combination of strategies is being further investigated in an SFOE P&D project “Renosource” to replace a 200 kW boiler with two indoor installed propane heat pumps with the two heat sources outside air and ground in practical operation over three heating periods by means of monitoring. The monitoring data can be used to validate and further develop the simulation models and to evaluate extended studies on system behaviour and control.

Impacts on the heat demand in the life cycle of ground probes

Ground probes are dimensioned with a very long perspective over 50 years regarding the evolution of the future ground temperatures. This provides a certain degree of certainty over the life cycle, as the capacity and energy requirements may decrease as a result of climate change and/or building renovation. The influence of global warming on the source design is considerably less significant than the impact of even a slight building envelope renovation. This means that even in a monovalent ground source system, taking into account renovation cycles can lead to dimensioning advantages. In multi-source systems, the savings potential in terms of the number of ground probes required increases massively.

Conclusions and perspectives

The investigations carried out confirm the potential to overcome the limitations of various individual sources and to enable monovalent heat pump operation using multi-source solutions. Furthermore, increased efficiency can be achieved by utilising the best seasonal temperature conditions and cost savings, in particular by reducing the length of probes in the ground probe field, which compensate or even overcompensate for the costs of the other sources, making multi-source solutions attractive even for applications without restrictions.

The combination of heat sources is not limited to the combination of outside air and ground probes considered here. Rather, the outside air is representative of a source with limited capacity, in the case of outside air for example due to noise protection requirements, and the ground is representative of a heat source that can be stored but may also be subject to restrictions. Other possible combinations include groundwater or surface water with a limited pumping volume or waste heat with limited capacity in combination with air or ground probes.

In the regeneration concept, the second source is primarily used to manage the primary heat source that can be stored. In addition, however, the regeneration source can also take over summer operation alone, for example, and thus utilise seasonal advantages, such as the good summer radiation available in the case of solar regeneration and the higher summer temperatures in the case of air heat exchangers, thereby further promoting the regeneration of the primary heat source. However, any increased complexity of the system must also be taken into account.

In some cases, the combination can also enable other operating modes, such as freecooling operation with the additional use of ground probes. However, the utilisation of these freecooling options also depends on surface emission systems in the building, which traditionally limits the application to new buildings, since radiators have too low surface for freecooling.

Monovalent heat pump solutions were analysed as part of the project. However, the concepts developed can also be useful for a combination with other heat carriers or heat generators. In combination with district heating or low-temperature waste heat, more buildings can be connected to the grid by covering the peak load with ground probes. The load profile for the energy drawn from the grid shifts towards more base load by increasing the proportion of hot water, i.e. the waste heat from wastewater treatment plants or district heating can be better utilised and existing grids can supply more buildings without increasing the pipe diameter/generator capacity or more heat is available for high-temperature applications such as existing buildings. These aspects are investigated in the upcoming SFOE project “PeaknCool4Districts”.

The results indicate that individual sources are sometimes economically inefficient and that better system solutions regarding efficiency and cost benefits can be developed using multi-source systems, which also enable monovalent heat pump operation by overcoming the limitations of individual sources.