BRIEF REPORT

Development and verification of a cost-effective method for the installation of horizontal ground loops for heat pumps

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for

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Background

Geothermal energy is a renewable energy source with an enormous potential, which is becoming more prevalent in Germany. Meanwhile the technical know-how to develop this potential exists and the application technologies for heating of residential buildings using heat pumps are available. This applies to electric heat pumps and gas heat pumps either. In many cases both the investment costs of the environmental thermal coupling as well as the installation costs in the case of horizontal ground loops limit the amount of installations in the field. Cost saving and reduced complexity in the installation process can promote the use of these technologies significantly.

The main objective of this project was a comparison of ground loops with and without excavation work in terms of function, performance, costs and effort to install. These panels have been installed at several sites with different methods and their effectiveness has been measured. Accompanying numerical simulations were performed for the interpretation and validated using data from the practical implementation.

Implementation

The overview of the use of shallow geothermal energy sources provides the basis for understanding the subsequent analysis and assessment of existing methods of installation. Both the conventional installation of ground loops as well as the possibilities of passing without earthwork activities are documented in detail. For the experimental phase of the project a tool for the implementation of the innovative installation-system is selected and tested by the project partner. For direct comparison of conventional and innovative technology and the subsequent utilization demonstration plants have been installed in different locations. Two plants (Berlin I and Essen) will be equipped with three horizontal ground loops that were used in each case with different insertion technique. Figure 1 shows the installation of the horizontal ground loops in Essen.

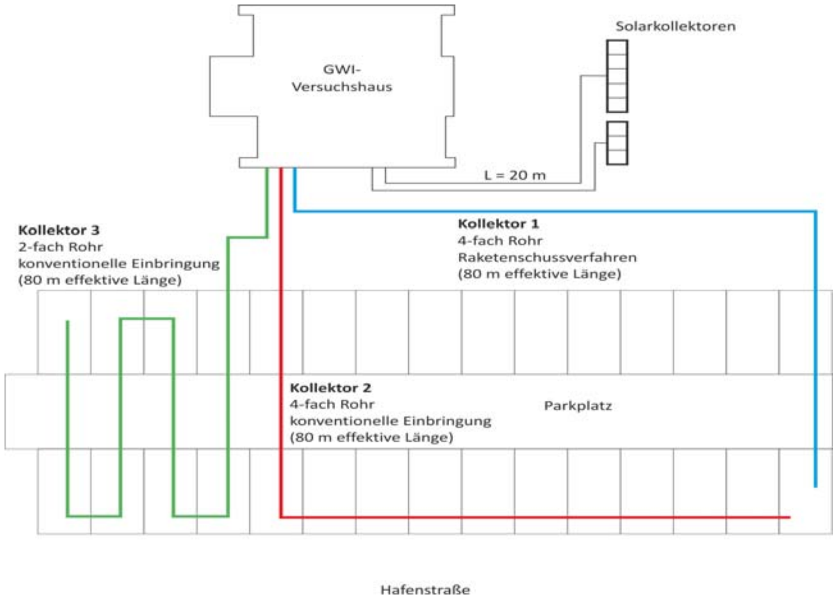

Figure 1: Installation of ground loops in Essen

Another location (Berlin II) has been used for verification of system parameters under realistic operating conditions. To this end a ground loop connected to an innovative test system under real load profile was operated. For recording the measurement data at GWI a data acquisition system was constructed which was then installed in the field with a remote data reading. Figure 2 shows the pilot plant data acquisition system. These measuring devices were then constructed at each demonstration or field test sites and put into operation.

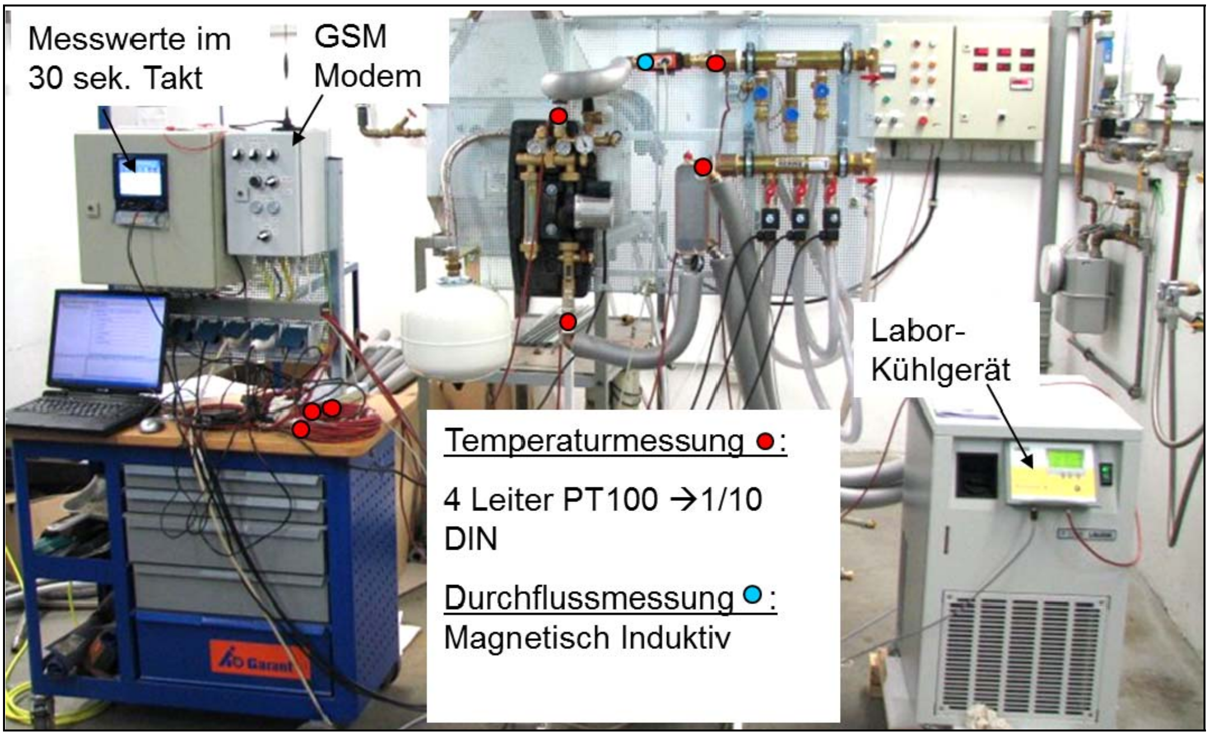

Figure 2: Pilot plant for data acquisition

For the design of the demonstration plant and a holistic approach for the comparison of different methods, the experimental test phase was accompanied by detailed numerical simulations and completed. The aim is to support the design and validation of future results. Important factors, such as pipe geometries and size, thermal conductivity of the soil and the pipe material and changes in water flow rate were investigated.

Figure 3 shows the results of the collector with different parameters and different horizontal ground loops.

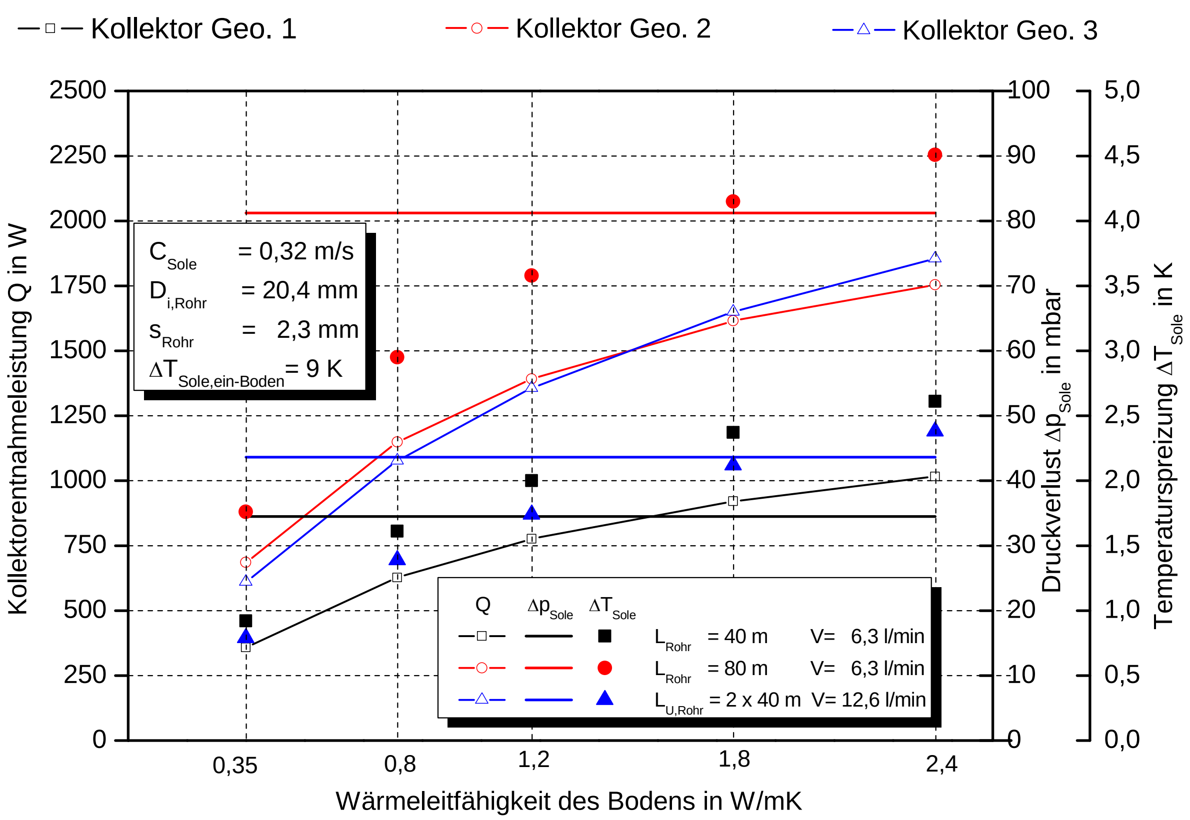

Figure 3: Numerical results of the collector taking performances at different parameters

Figure 4 shows a direct comparison of the results of a numerical simulation with measured values of horizontal ground loops installed in Essen. The results of the simulation show a maximum deviation of 2.6 % compared to the measured values, so that accuracy is ensured in accordance with the case of a real operation simulation. In contrast to the simulation of the individual factors (see Figure 3), which were conducted to study and design parameters, Figure 4 shows the comparison of actual measured values with a simulation based on actual operating conditions in Essen.

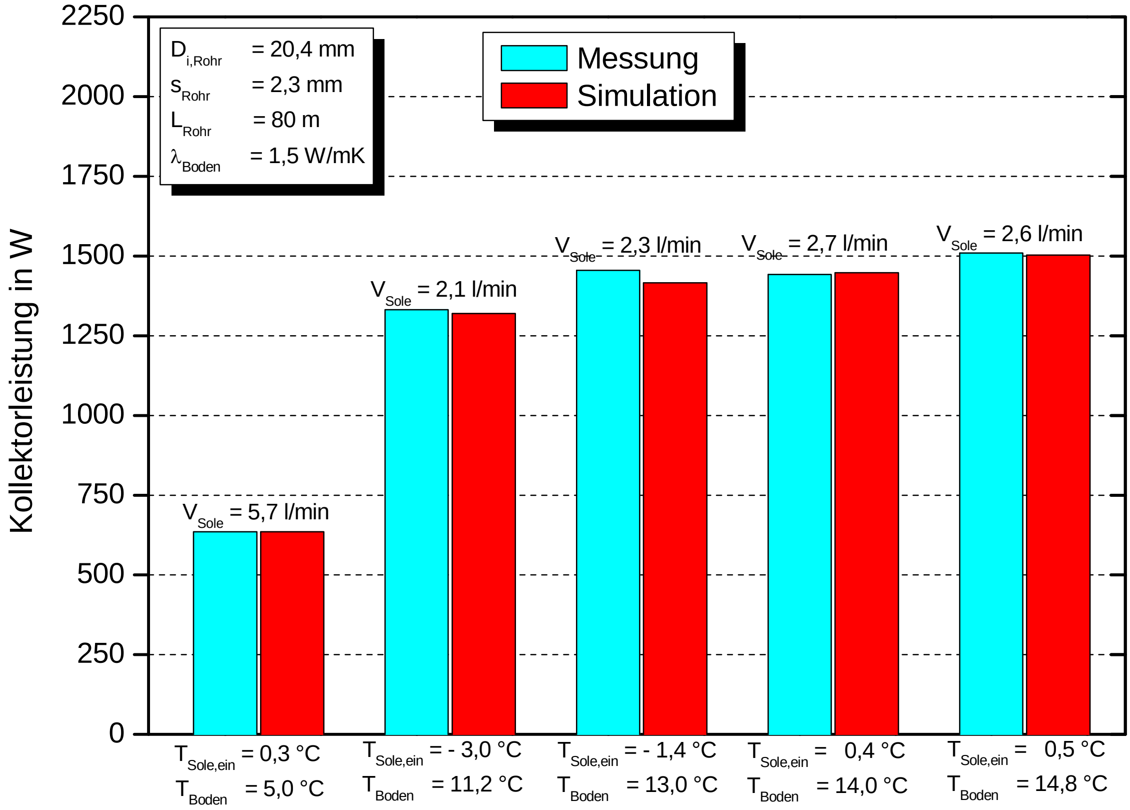

Figure 4: Comparison of results from the simulation and measurement

Experience and results of the demonstration projects

In retrospect the experiment has shown some difficulties. The experimental site was mainly chosen according to their feasibility, regardless of geological and hydrological conditions. Factors, such as soil, a seasonally fluctuating water table, shade or sun exposure by partial irregular construction, cultivation cause an irregular heat input and influence caused the regeneration ability of the soil. The measurement systems have been completely remote controlled. A failure-prone connection to the first plant was removed by a repeater installed in January 2010.

The main problem was the discovery of sites for the establishment of demonstration systems and the procurement of gas pumps. As a substitute for the unavailable gas heat pumps a cryostat (as a heat sink) was installed in Berlin-Werndorf. The system was not able to ensure temperatures below 0 ° C for the heating return to recover heat from the ground at low temperatures. Furthermore the temperatures were about 3 ° C below the reference temperature in winter 2010. And the sunshine duration has been reduced to approximately 40 % compared to the reference period [1].

Normally this is not the case in practice - higher temperatures can be expected and consequently, higher power. A direct comparison of the horizontal ground loops was ensured at two locations. The third location (Berlin Nottenpfad) a horizontal ground loop was installed via the innovative technique, a comparison with conventional methods is not possible. However, this system could contribute to the validation of existing data.

Finally all of the individual locations collectors have similar measured values. The innovative method is only slightly worse considering climatic influences and delayed operation. Figure 5 shows some results in Essen from the period February to June 2011.

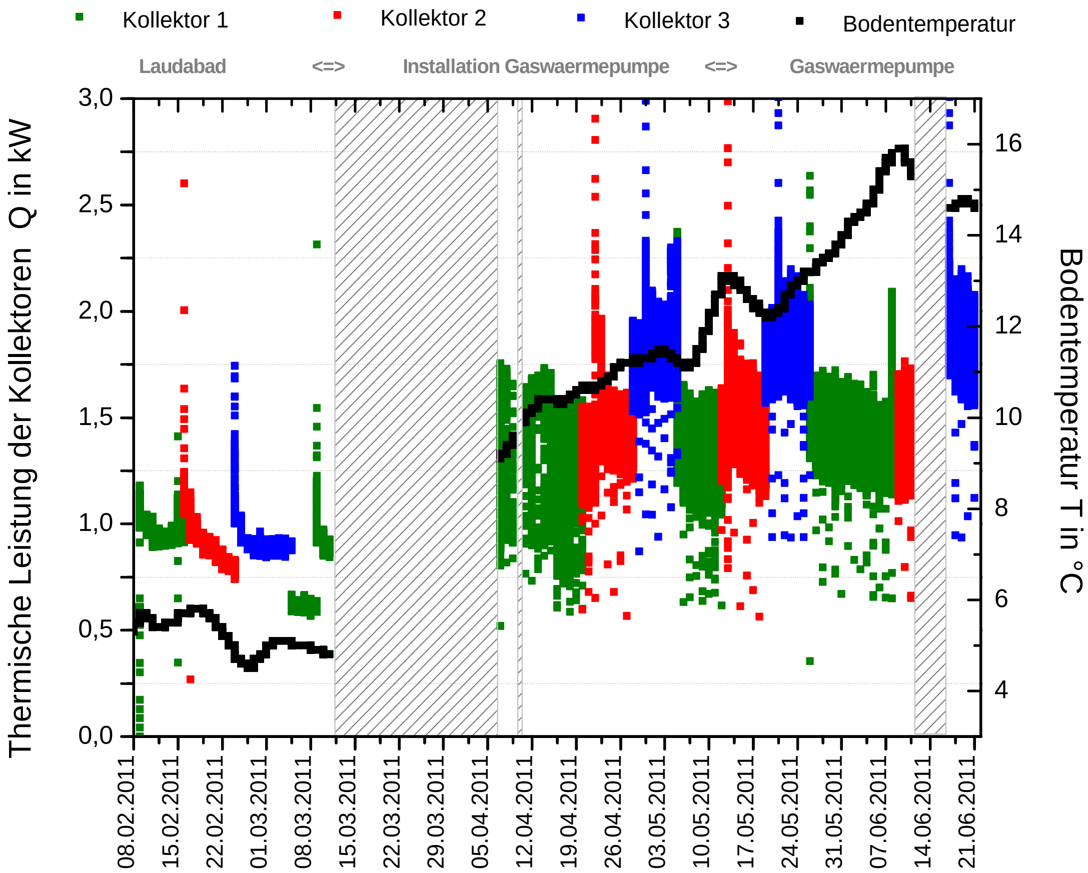

Figure 5: Collector-withdrawal capacity between February and June 2012 (Essen)

Individual temporary differences in the horizontal ground loop performance may be due to regional impact of soil characteristics (e.g. soil moisture content). A high recovery is demonstrated by performance differences. The longer a soil is regenerated, the higher its achievements. This fall goes after a while again to a constant level. A regeneration through the summer is necessary for a stable continuous operation of the ground loops.

The horizontal ground loops performance dependent on the soil temperature and the temperature difference from the in- and outflow temperatures ($\Delta\vartheta$) of the heating system. The higher the temperature difference the higher the benefits obtained. For high performance the flow temperature should be substantially less than the soil temperature. Low flow temperatures must be avoided in order to avoid excessive extraction of heat or freezing. Freezing of the soil around the horizontal ground loops may cause damage. Natural regeneration is hampered by extensive glaciation and subsequent performance issues are possible.

Such a shutdown took place in February 2012 in Essen as the flow temperatures in the collector reached -10 ° C and the soil temperature reached 3.7 ° C the system turned off. Figure 6 shows the time period just before the shutdown.

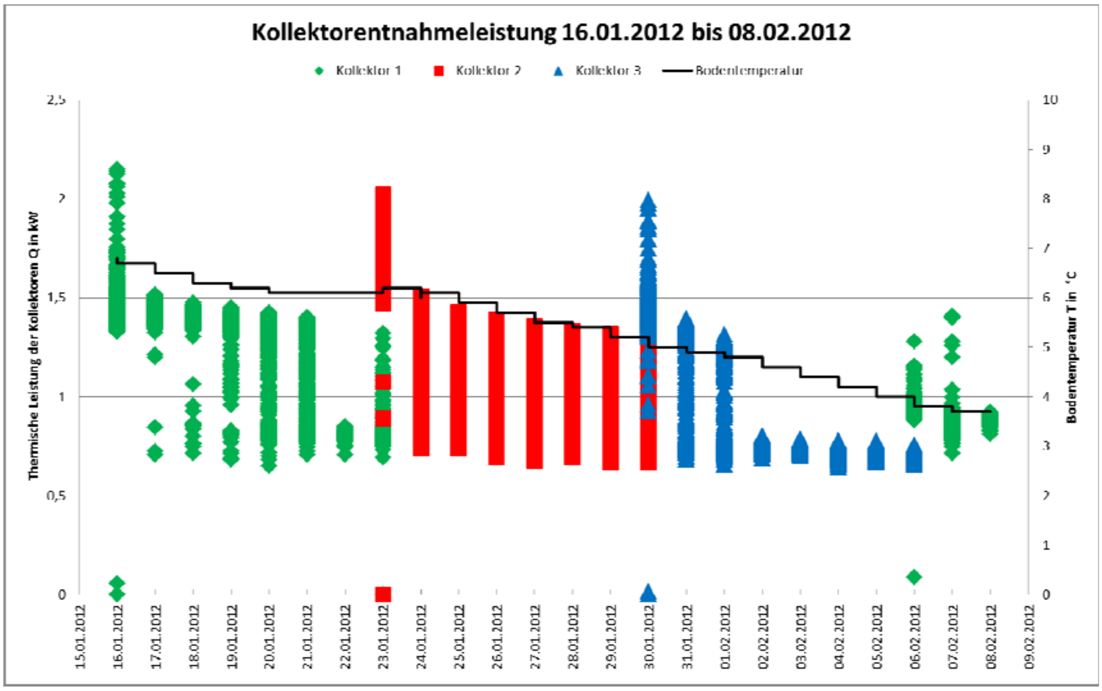

Figure 6: horizontal ground loop-withdrawal capacity before shutdown February 2012 (Essen)

Figure 6 shows a significant drop in performance due to the low temperature difference ($\Delta\vartheta$) of the horizontal ground loops. The exact temperatures are shown in Figure 7.

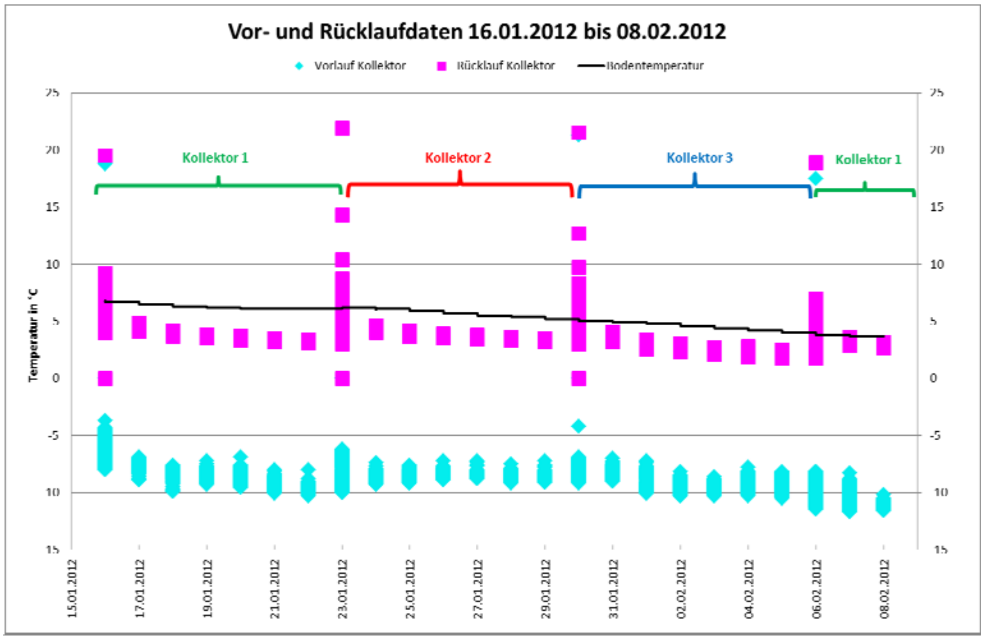

Figure 7: Heating flow- and return temperature data before shutdown February 2012 (Essen)

Assessment of the process and comparison with other systems

The data analysis shows that the innovative method of installation does not lead to serious disadvantages concerning heat output. The system shows a behavior similar to a conventionally installed horizontal ground loop. Regading the types of collectors within the project no clear difference was observed. The quadruple collector works as well as the simple collector despite its larger exterior surface and achieved the same benefits. In practice therefore the latter will be found because of the lower material costs.

The aim is to evaluate the technical possibilities of innovative installation technology from horizontal ground loops and related economic aspects. Since the performance of conventional systems approximately the innovative installation process corresponds, this new method benefits by the reduced burden and cost.

Below an example for an estimated cost calculation using a 6-7 kW heating system is outlined. This corresponds to the heating load of an average low-energy single-family home. The costs can be used as a guide, since a number of factors affect this, such as heat content of the soil, type of soil, type of material, individual companies offering expenses, etc.

The most expensive option is the conventional collector with approx. 10,000 €. Horizontally ground loops, thereby incurring costs of € 4,000 up to € 5,000 if they are introduced with a tunneling device. The newly developed and optimized method is about 2,000 to € 3,000 less than the cost of the previously used methods in practice.

An approximate cost summary[1] is listed in Table 1.

Table 1: Overview of costs of different systems [2]

Plant variation	treatment	estimated costs [€]
Ground loop, horizontal	conventional	10.000
	Compression drilling	10.000
	Wash drilling	6.000 - 8.000
	Rocket-type drilling	4.000 - 5.000
	innovative treatment	2.000 - 3.000

The cost of a gas heat pump and a soil report are not included (from approx.. € 10.500).

Conclusion and outlook

Based on the measurement results only small differences in performance between the conventional introduced ground loop and innovative system have been determined. The innovative method is about 1/3 cheaper and therefore much more economical compared with conventional systems.

Furthermore, the innovative method represents a much simpler and faster way to install horizontal ground loops. As one disadvantage increased care should be mentioned in the passing of "drilling instruments", particularly on stony ground. There may be variations in the drive-through.The outlook for further research especially proprietary optimization of the process (e.g. leading in rocky terrain, the amount of wash water, etc.) and improvement are to be mentioned in ground loop tube geometries and materials. These improvements are expected to be done by the manufacturer. Overall it can be stated that can benefit from the extended scope and market segments and customer groups with renovated buildings by the use of these heating systems in combination with the type of installation since elaborate excavation work can be omitted and the room requirements are lower.

Literature

[1] German Weather Service, URL: http://www.dwd.de, query date 11.02.2010

[2] Interview, Interview of Dr. Bohmann, CEO of BEGA.tec GmbH, Berlin, Stand: 27.08.2009

[1] The costs of the installation method without extensive earthwork activities are based on current estimates of BEGA.tec. Currently there is a prototype method. Cost reductions can be expected in the future.