Drilling Curved Borehole Heat Exchangers to enable Shallow Geothermal Everywhere

Canopus Drilling Solutions

Authors
Canopus: Diederik Wawoe, Jan Jette Blangé
IF Technology: Daan den Hartog, Bastiaan Rus

1 Executive summary

Shallow geothermal wells are drilled up to a depth of 500 meters for borehole heat exchangers (BHE). These BHEs are combined with heat pumps for sustainable heating and cooling of households. Traditionally shallow geothermal wells are drilled vertically. Research shows that curved shallow geothermal wells will produce more effective heating, because curved geothermal wells make better contact with the lower and hotter earth layers. Furthermore, it leads to fewer wells needing to be drilled reducing the required footprint of the wells. Canopus innovative directional steel shot drilling technology makes drilling of curved shallow geothermal wells more cost effective. This leads to overall cost reduction of the project and obviously to a smaller footprint

2 Introduction

Shallow geothermal systems are a type of renewable energy technology that extract heat from the ground up to a depth of 500 meters. The depth is usually restricted by local regulations, which can make obtaining permits for drilling deeper boreholes difficult. The temperature level of these systems varies based on the site's climatic conditions and the temperature gradient, which refers to the increase in temperature with depth in the ground. In the Netherlands, this gradient is about 3 degrees per 100 meters. When combined with the average temperature of the soil's top layer, which is around 10°C, the temperature can increase to as high as 25°C at a depth of 500 meters, see Figure 1.

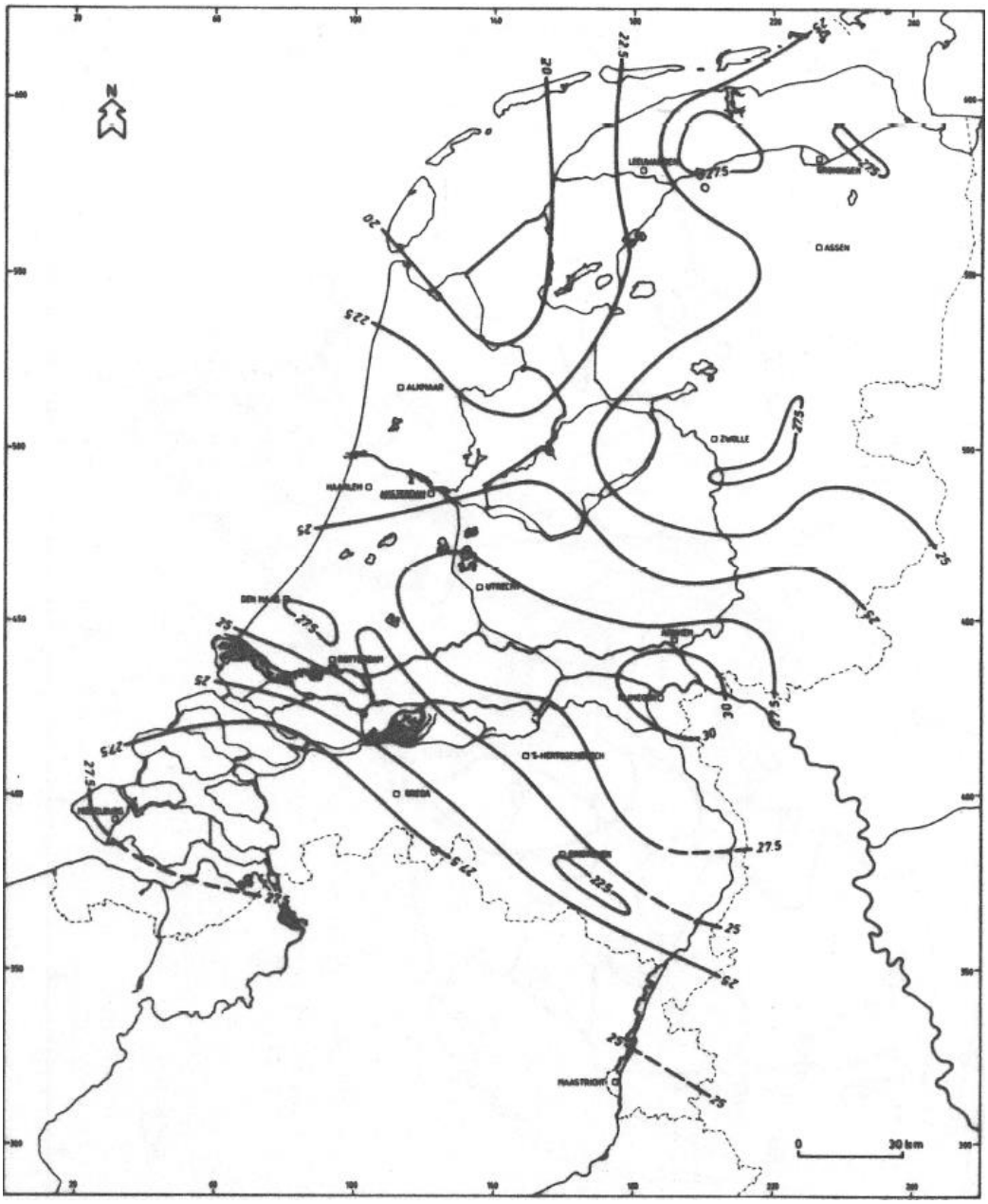

Figure 1 | Subsurface temperatures at 500 meters bgl.

To access this thermal energy, one or more boreholes are drilled into the ground. In closed-loop geothermal systems, U-shaped pipes are inserted into the boreholes and sealed with a concrete mixture. A liquid, such as a brine, circulates through the pipes, absorbing the thermal energy stored in the ground and transferring it to a ground source heat pump. The heat pump uses this energy to evaporate a refrigerant, which is then compressed to the desired temperature level for heating or domestic hot water heating. More information on how heat pumps work can be found on our website: www.canopusdrillingsolutions.com

In general, geothermal heat pumps deliver maximum temperatures of 50-55°C for heating purposes, while newer systems are being developed that can achieve temperatures up to 85°C. For cooling, the maximum temperature reduction is typically around 6-7°C. Geothermal heat pumps consist of three main components: the ground-side system that extracts heat from or deposits heat into the ground, the heat pump that converts the thermal energy to a suitable temperature level, and the building-side system that transfers the heat or cold into the rooms. By utilizing the thermal energy stored in the ground, geothermal heat pumps offer a renewable and sustainable alternative to traditional heating and cooling systems.

Also see Figure 2: BHE
From:
https://geothermalcommunities.geonardo.com/assets/elearning/6.11.Shallow%20Geothermal%20Systems.pdf

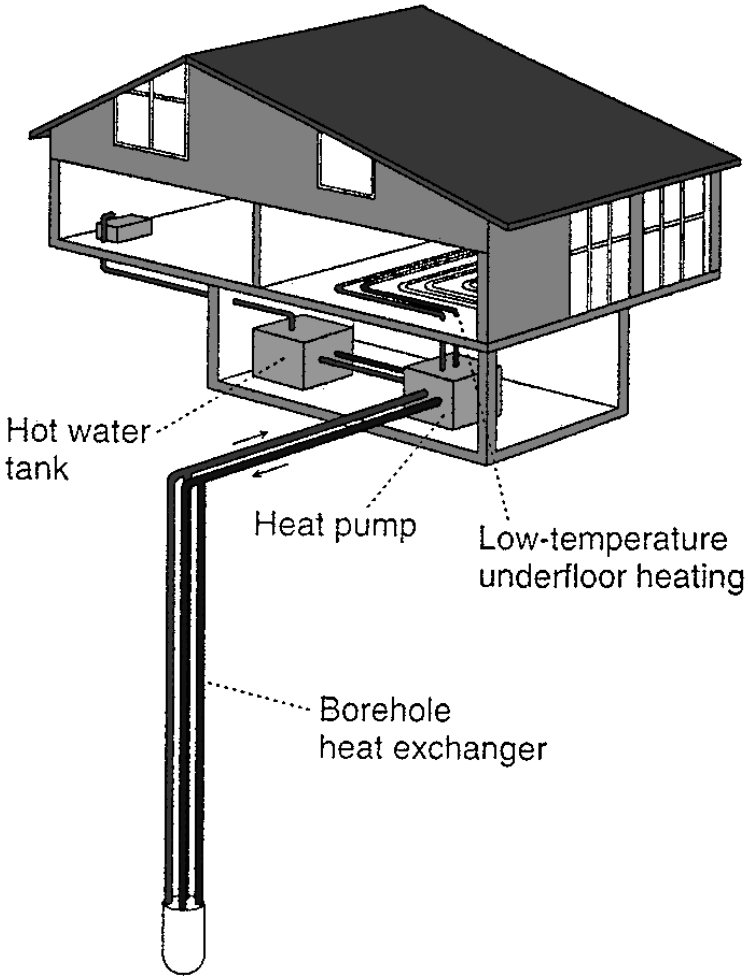

Figure 2: BHE

(from: https://www.geothermal-energy.org/pdf/IGAstandard/ISS/2001Romania/rybach.pdf)

3 The problem: conventional closed-loop geothermal systems are suboptimal

Traditionally wells for closed loop systems are drilled vertically. Although this may work well for use in a single home. A more efficient way to use the temperature from the soil is to drill curved wells.

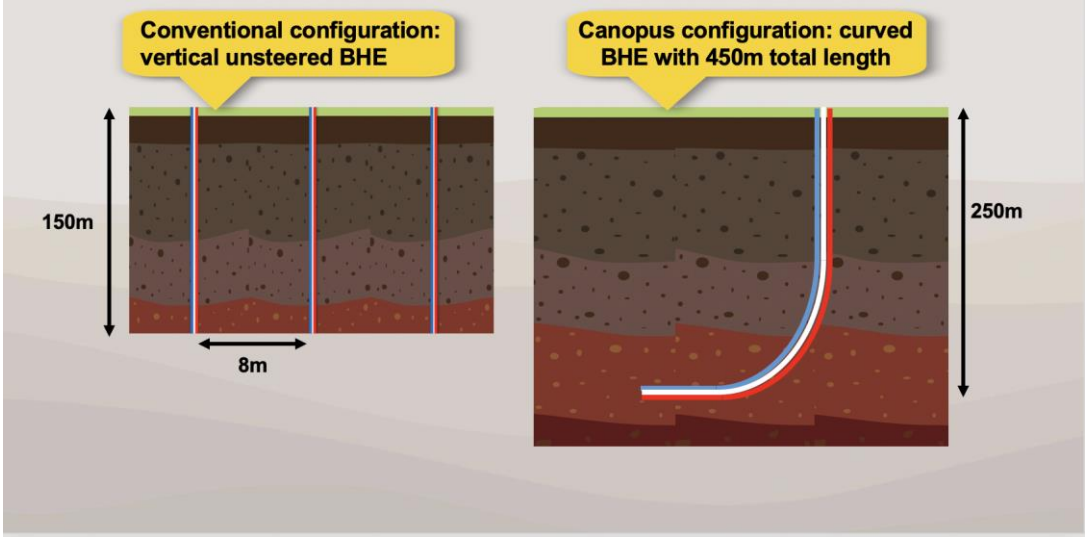

Figure 3: vertical shallow wells vs curved shallow wells

Several studies have been conducted to analyze BHE efficiency with different setups.

IF Technology researched the effects of greater borehole depths on the BHE efficiency (2018). It was shown that the total BHE-length can be reduced by drilling deeper wells on an equal surface area. The same amount of energy can be delivered with 150 wells up to 150 m bgl (total length: 22.500 m) as with 40 wells up to 300 m bgl (total length: 12.000 m). The energy per meter well length is almost twice as high for deeper wells.

Two main principles can probably explain this difference. Firstly, the soil temperature increases with depth. As a result, the average initial soil temperature is higher in deeper wells, leading to better efficiencies. Secondly, a greater soil volume is addressed for heat extraction in the deeper well situation. The occupied surface area is the same in both scenarios, but a greater soil depth is used with deeper wells, leading to higher efficiencies.

Parry et al. made a comparison between vertical BHE's and inclined BHE's. In this research 55 BHE's, each 200 m in length, were simulated. The research showed that inclined BHE's are 30% more efficient than vertical BHE's. In other

words, more energy can be subtracted from inclined BHE's than vertical BHE's on the same surface area.

The results from Parry et al. can also be explained by the increase in addressed soil volume with inclined BHE's. Higher soil volumes increase the efficiency of BHE's.

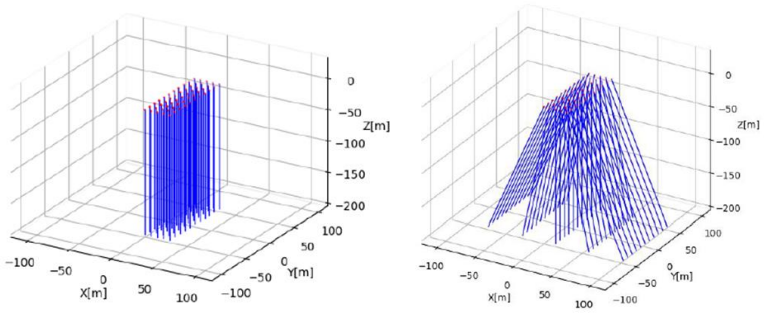

Figure 4 | Vertical wells and inclined wells from Parry et al.

4 The solution: drilling curved closed loop geothermal systems with steel shot

Until recently, drilling curved bore hole heat exchangers was considered an expensive and challenging task, largely due to the conventional drilling techniques inherited from the oil and gas industry. These techniques typically employ a heavy weight on the bit, leading to steering difficulties and vibrations in the system. Mechanically removing rock using Polycrystalline Diamond Cutter (PDC)-bits, for instance, requires a 15 cm diameter bit to be subject to a weight of 5,000 to 10,000 kg. The high cutting force demands that the drilling assembly be very stiff, resulting in directional control challenges, drill string vibrations, and down hole electronics difficulties. Additionally, drilling a side-track is cumbersome, and the tight annuli of the stiff bottom hole assemblies cause enhanced circulation pressures, bore hole wall erosion, and friction.

To address these challenges, Canopus technology introduced directional steel shot drilling, which removes rock by exposing the hole bottom to a high pressure jet that contains steel shot particles. This approach requires minimal weight on the bit and uses conventional flow rates, resulting in good solids transport and well control and the ability to drill through any rock type. Additionally, this technology offers advanced steering capabilities based on differential hole making.

Currently, Canopus is preparing to introduce this technology to the market after conducting successful lab experiments in 2021. This development could potentially reduce the cost of drilling curved bore hole heat exchangers while improving steering capabilities and reducing vibrations in the system.

(also see for details: from Blangé-Novel_Directional_Steel_Shot_Drilling_Technology_for_short_radius,_long_reach_multilaterals-273_c)

Figure 5: The spherical steel shot particles - diameter 0.6 to 1.2 mm. Picture by Tessa Veldhorst De Schaapjesfabriek©.

5 The benefits

Several benefits can be assigned to the curved BHE.

Optimal use of temperature gradient in the soil
Soil temperature increases with depth. As a result of the curve in the Canopus BHE, a larger part of the BHE exists in warmer regions. Below, a theoretical case study is elaborated to quantify this benefit. For the case study, a linear soil temperature gradient of 10°C to 12°C is assumed between 0 and 200 m bgl.

When we assume a vertical BHE up to 150 m bgl, the average soil temperature equals 10,75°C. If we create curved BHE in the same soil section (up to 150 m bgl), the average soil temperature over the BHE equals 10,9°C. When the deeper section of the BHE becomes even more inclined, the average soil temperature increases even further.

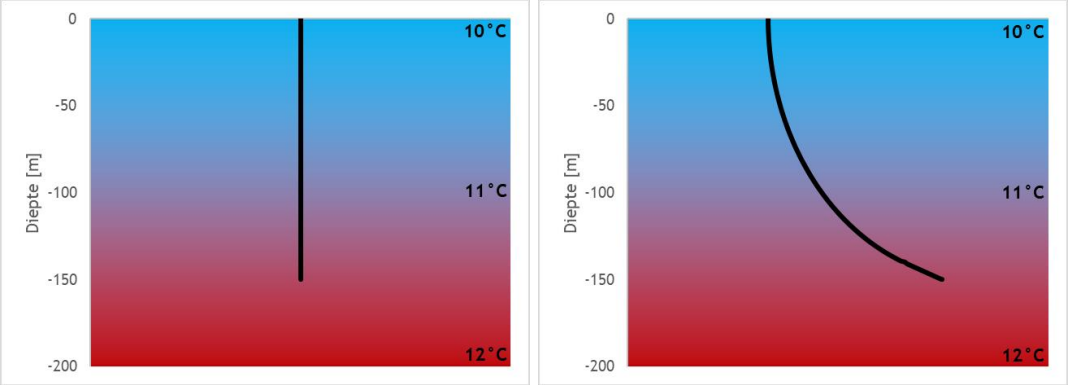

Figure 6 | Initial soil temperature with a vertical BHE (L) and a curve BHE (R)

Bigger BHE length at the same depth
The efficiency of BHE's increases when larger soil volumes are addressed by the BHE. As a result, the longer the BHE, the more energy can be subtracted from the soil. A curved BHE can reach a length of 210 m, within a borehole of only 150 m bgl, which is an increase of approximately 40%.

Sometimes, local legislation allows a maximum drilling depth. The Canopus Drilling technique allows to create longer well lengths without exceeding a certain depth, leading to higher efficiencies than with vertical BHE's.

Creating larger BHE length at certain suitable depths
Besides the initial soil temperature, several soil properties influence the BHE efficiency. Heat capacity, thermal conductivity and groundwater flow are important variables. Creating greater BHE lengths at depths where properties are beneficial, by steering the borehole, increases the efficiency of the BHE.

Addressing larger soil volumes from small surface areas
Sometimes the surface area for drilling is limited. For example, in built areas. The Canopus drilling technique allows to address a large soil volume from a small

surface area. With vertical wells on a small plot, the addressed soil volume is limited by the maximum drilling depth. When the BHE's can be curved in all directions from a central point, the addressed soil volume increases significantly, without the need of larger surface areas. As a result, the efficiency of the BHE's increases.

B**ased on the studies referred to in this section, IF technology believes that an increase of 30-50% of effective borehole length can be expected from drilling curved borehole heat exchangers, depending on the inclination, compared to regular vertical BHEs.** In addition to the increased subsurface volume, the higher average temperature could result in a 10-30% efficiency increase measured at the heat pump.

Concluding: by activating more subsurface volume, with a higher average temperature, curved borehole heat exchangers have a significant performance increase compared to their vertical counterparts. Resulting in material cost reductions or enabling shallow geothermal energy in places where it wasn't possible before due to limited space on the surface.

6 What you can do

If you are a developer or owner of a facility with a heat demand at least equivalent to 100 living units and if you want to reduce your gas price, if you do not want to waste much of your plot on drilling several geothermal borehole heat exchangers. Contact us by email: info@canopusdrillingsolutions.com

7. About

CANOPUS DRILLING SOLUTIONS GEOTHERMAL BV

Canopus Drilling Solutions Geothermal BV is a start-up company founded in 2019. Canopus develops novel hole making technology with unique capabilities. The Steel Shot Drilling technology has been field-proven but shelved by the oil and gas industry, but Canopus developed a method for directional control, patented the solution and has built a lab prototype. Canopus commercializes the innovative drilling technology and advanced underground navigation for shallow and deep geothermal development, since the capabilities of the steel shot drilling are considered a game-changer for low cost geothermal reservoir development. The Canopus team has over 40 years of experience with well construction technology development and commercialization and is seasoned in participating and leading multi-party, multi-national consortia. Canopus also have a powerful network of hardware manufacturers for well construction equipment.

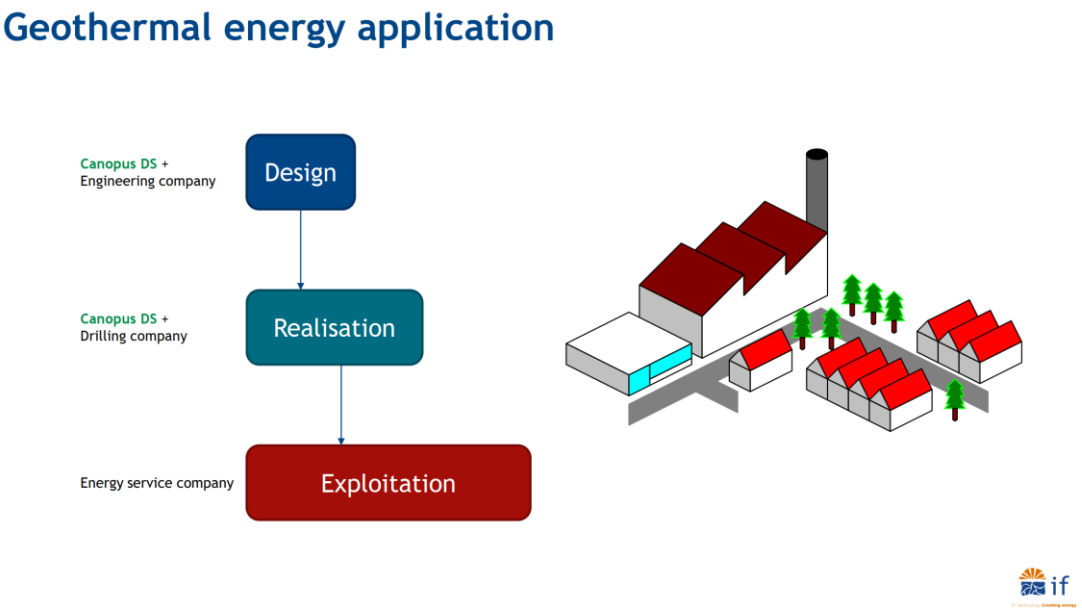

Figure 7 | Schematic representation of possible partnerships with the geothermal energy industry.

Contact:
Diederik Wawoe
Director
M +31655101519
E Info@canopusdrillingsolutions.com

IF TECHNOLOGY

For 30 years, IF Technology has had a significant impact on the energy transition. IF technology is always looking for the best solution, because no project is the same. From our broad perspective, IF Technology advise on technical feasibility, calculate the financial impact and consider how to organize this. Our specialization lies in situations where collective solutions with soil energy, geothermal and aquathermal energy seem possible, but we certainly do not limit ourselves to this. We can also handle hybrid forms or individual solutions! Read on to see who we are and what we can do for you.

Who are we?

We are a consulting and engineering company specialized in building and area development. We mainly advise governments, developers, building owners and energy suppliers on how to make the step to sustainable heating and cooling.

Imagine, build and manage

We are always looking for the best solution, because no project is the same. From our broad perspective, we advise on technical feasibility, calculate the financial impact and consider how to organize it. You remain the director, with IF as your reliable partner at your side. Read here how we work for and with you: from conception to construction to management.

Consultancy and engineering

Developing a sustainable energy supply can be a complex task. You have to take into account many parties involved, each with their own interests. Does each party have all the options in view? Does everyone know what is allowed? How will you organize this?

Besides giving expert advice, we also have real engineering know-how. So we do not limit ourselves to just advising, but actually take an idea further into design and engineering. With this, we offer a complete pallet of work in the process of conceiving, building and managing sustainable energy systems.

Contact:
B.M. Rus MSc
Projectmanager
T 026 353 5594
M 06 11 50 59 42
E b.rus@iftechnology.nl