The new black gold

Geothermal energy is rapidly gaining in popularity, thanks in part to ambitious climate goals and steep gas prices. TU Delft plans to pump up hot geothermal water from deep in the ground to heat the university's buildings.

Tomas van Dijk

It is almost like a kaleidoscope: grains of sand in changing shades of white and grey light up and continuously create new colour patterns. To create this play of colours, mining engineering student, Douglas Gilding, has placed a wafer-thin layer of sandstone under a light microscope and simply changes the polarisation direction of the light source.

Back in 1953, this small piece of sandstone was brought up from a depth of two kilometres below the surface at a location near the fire department station on the Krakeelpolderweg in Delft. At the time, a Dutch gas joint venture (called the Nederlandse Aardolie Maatschappij (NAM)) was drilling at this site to determine if any oil or gas was present.

"This stone seems promising," Gilding says. "It has a porosity of 25 to 45 percent. Under the ground, all those holes in the stone were filled with water." He then places a piece of stone from a well dug near Moerkapelle (12 kilometres east of Delft) under the microscope: "Here and there you can see some traces of oil, which is a bit of a shame."

Delft Aardwarmte Project

Not oil or gas, but rather hot water – that is the mineral increasing numbers of mining engineers and geologists are now searching for. As is Gilding. Two years ago, he and some fellow students devised a plan to determine if the hot geothermal water beneath the TU campus could be exploited to heat buildings. The students presented their plan, called the Delft Aardwarmte Project (DAP – or Delft Geothermal Heat Project), during the 115th anniversary of the Delft Mining Engineers Association. "We wanted to come up with something other than the usual building of a tower made of beer crates," recalls Gilding, who is now the secretary of the DAP Foundation. "We wanted to pull off a feat that would help make TU Delft more environmentally friendly."

Twenty mining engineering students have since devoted their graduation projects to the development of a feasibility study, and thanks to their collective research efforts TU Delft recently obtained an exploration permit from the Ministry of Economic Affairs. The university now has the right to search for geothermal heat in a 61 square kilometre area in the municipalities of Delft and Pijnacker-Nootdorp.

TU Delft's Rector, Professor Jacob Fokkema, a geophysicist himself, has embraced the project: "It's a wonderful showcase for sustainable energy right on our own campus." The students are working together with local commercial gardeners and produce growers that want to use the hot water to heat their greenhouses, and it is these companies that are the main driving force behind the current surge in interest in geothermal energy, or geothermics. Since mid July 2009, the Ministry of Economic Affairs has received around 50 applications for drilling permits, with many of these requests coming from commercial gardeners and produce growers in the Zuid-Holland region. This stands in sharp contrast to the preceding years, when the ministry received only a few such applications.

These local commercial gardeners were inspired by tomato grower, Rik van den Bosch, from Bleiswijk, who was fed up with the high and sharply flucuating prices of gas. In 2008, he was the first commercial grower in the Netherlands to extract geothermal energy. Van den Bosch had two wells drilled, each to a depth of nearly 1800 metres. One well is used to pump up 60 °C water, the other to drain off the water after it has cooled down to 30 °C. Pumping back the water is necessary to prevent subterranean friction in the stone layers.

'DAP wants to experiment with a new drilling technology that uses tubes made of carbon composite instead of steel'

Today, 150 litres of hot ground water is now flowing through the approximately seven hectares of greenhouses where Van den Bosch grows 18 million kilos of tomatoes each year. Thanks to these wells, he saves five million cubic metres of natural ▸▸

Photo: Nout Steenkamp/fmax

gas a year, which accounts for 90 percent of his annual energy consumption. Van den Bosch expects to recover his 6 million euro cost of investment in five years.
TU Delft is also envisioning similar figures from its plans to pump up hot geothermal ground water. The university would thus be following an example set by a handful of geothermal housing projects started in the Netherlands in recent years. Elsewhere, other municipalities and housing corporations in the Netherlands are also keen on using geothermal heat. In October 2008, Heerlen, a city in the southeastern Netherlands, began pumping up hot water from abandoned mineshafts to heat newly built houses. And in The Hague, housing corporations and energy companies want to heat 4,000 new buildings and homes with the geothermal heat contained in a layer of sandstone.

'We wanted to pull off a feat that would help make TU Delft more environmentally friendly'

The geothermology of heating homes and buildings is however more complex than for heating greenhouses. In countries like the Netherlands, where ground water temperatures are lower than 100 °C, generating electricity is too costly. For homes and buildings, the energy tapped from ground water must flow through an expensive installation equipped with heat exchangers.
'The main argument for heating buildings in the Netherlands with geothermal heat is environmental," says a press officer from Eneco, one of the energy companies involved in the geothermal water project in The Hague. "Drilling is expensive, and constructing the network is also expensive, because the tubes must be thicker than the gas pipes. Therefore, from a strictly financial perspective, you shouldn't do it. But the main advantage of geothermal heat is that no CO_2 is released during the entire process, except for a tiny amount that comes from powering the pump."
An important condition is that there must be purchasers in the vicinity of the hot geothermal water well. There must also be a power station nearby for the combined production of electricity and heat, as well as a network of pipes. In this respect, the TU Delft students seem to have had a stroke of luck: there will indeed be plenty of local consumers of geothermal energy in the near future. The municipality wants to use an extensive network of pipes to heat newly built homes with the residual heat of nearby factories. "That hot water can be nicely supplemented with geothermally heated water," Guilding says. According to DAP's plan, a two-kilometre deep well will be dug close to TU Delft's cogeneration station on the Leeghwaterstraat, from where water with an expected temperature of nearly 80 °C will be pumped up. To make all this a reality, however, a partner must be found that is willing to exploit this energy source and cover the investment costs.
Eneco has expressed interest. "We're very enthusiastic," says Eneco's director of general affairs, Pieter Jan Witvliet, who hopes the project can be set up and executed in the coming year. Although Witvliet does not offer any firm commitment on Eneco's part, he does say that he's convinced "the project will take off."
Eneco is especially interested in DAP's plan to experiment with a new drilling technology, which involves using tubes made of carbon composite instead of steel, with the idea behind this being that since carbon composite is lighter than steel, drilling with carbon composite tubes will require a smaller drilling platform. "Drilling with steel requires a whopper of a drilling platform, and in crowded urban areas we often don't have the space to accommodate such platforms," Witvliet explains.

Underground flows

TU Delft and DAP also want to study the underground hot water flows. Gilding: "We want to put lots of sensors in the well to measure the pressure and temperature and to map the water and heat flows."
TU Delft expects the Ministry of Economic Affairs to green light the planned geothermal explorations this autumn, after which drilling for hot water can commence. If the amounts of hot water prove to be as large as anticipated, a second well needed for exploitation could be drilled immediately afterwards.
The ministry's authorization for the exploration of the geothermal energy (granted this summer) was initially delayed because there turned out to be rivals in the field. The municipality of Pijnacker-Nootdorp had also requested permission to search for hot water sources, and a number of commercial gardeners in the area also have advanced plans in place for drilling. In July, however, the municipality of Pijnacker-Nootdorp decided to collaborate with TU Delft and DAP.
On his computer, Gilding studies a 3D image of subterranean Delft and its environs. Colored lines indicate the wells, although their exact locations remain uncertain. "That depends on the geological model we're developing of the substrata," Gilding explains. "To ensure we don't get in each other's

Photo: Sam Rentmeester/fmax

way, we must predict exactly how the water will flow once it has cooled down and is being pumped back into the ground. And we must also map the pressures in the ground caused by the circulation of water."

Drilling in the wrong locations should, obviously, be avoided. The Delft sandstone – thusly named because the ground under the city is so rich with it – was deposited here by the rivers some 150 million years ago. River sandstone is however notoriously treacherous, because the continually meandering rivers often take 'bites' out of thier own, older sedimentation.

'The geothermology of heating homes and buildings is however more complex than for heating greenhouses'

"We must grasp the full complexities of the rivers," Gilding notes. "And that's why we're studying under the microscope the grains of sand that NAM had collected in this area. If the grains of sand are round, the river has probably transported them a long way. If they're angular, they've travelled shorter distances. Using this kind of data, we're trying to trace the history of the area."

The stones form a fantastic subterranean landscape. Tectonic plate shifts, as well as meandering rivers, have helped create subterranean mountains. The African continent, for example, collided with Europe before once again retreating. Such shifts have caused many ruptures in the ground.

"You're never 100 percent certain that you're drilling in the right layer of sandstone," says Jan de Coo, from Pan Terra, a geological exploration company. Pan Terra has analysed the underground for the two commercial gardeners in Pijnacker-Nootdorp, and for the tomato grower in Bleiswijk. His company is also supporting the DAP Foundation's investigations. De Coo: "In Bleiswijk, the nearest test well – the spot from which we can therefore know with certainty the stratification of the ground – was four kilometres away. Based on the data from that well and on seismic data, we make an educated guess about the situation underground.

"Many blunderers simply draw straight lines between the layers of stone detected during test drillings in the area," De Coo continues. "And that's dead wrong," adds his colleague, Wiebe van Driel.

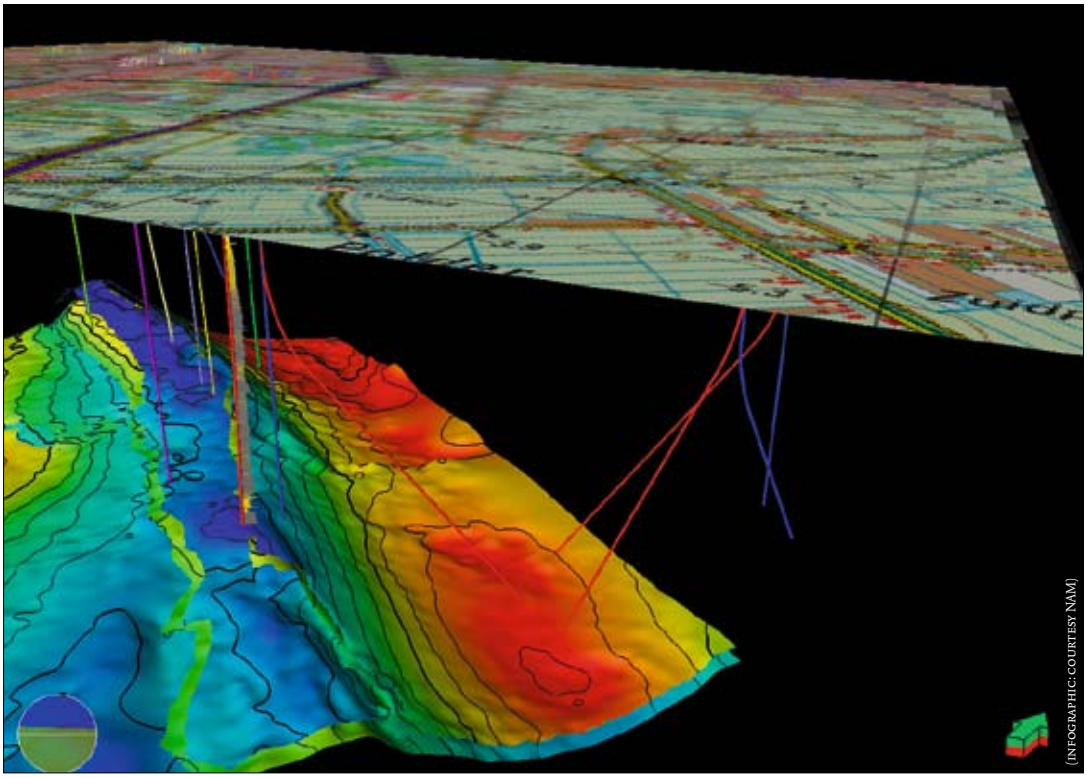
"To be able to determine the exact stone patterns, you must know during which sedimentation period the ruptures occurred."

The commercial gardeners, energy companies and geologists have nothing to complain about in this regard, the two researchers maintain. "Nowhere else in Europe is there so ▸▸

much information available about the condition underground," Van Driel says. "And that's due to the thousands of oil and gas drillings and test drillings that were done here in decades following the second world war."
Analysing drilling cores is part of Pan Terra's work. Oil companies are obliged to submit a representative selection of their excavated materials to TNO, an independent Dutch research institute. In a warehouse in Zeist, TNO has amassed more than 100 kilometres of drill cores, a TNO employee reveals.

Cold fronts

DAP's geological model not only shows the different layers of stone, but also how the underground cold fronts will spread very rapidly once the wells become active. After a few decades, the cold water that was pumped back into the ground will once again have reached the suction points. Pan Terra says that by that time the water will be hot again. "It's generally assumed that after more than 30 years, and at a depth of 2000 metres and a distance of 1500 metres between the pumping up and pumping back locations, the cold water will have long since been reheated," De Coo states.
Gilding disagrees. "The water will not even be close to being reheated after 30 years. The calculations aren't yet finished, but that it will take more than 100 years is already certain."
"In a sense, the geothermal heat we tap will not be an inexhaustible source of energy," Gilding says. "In 30 years time the TU will have to have ensured that it can also heat its buildings with 60 °C water."
Such scientific disagreements are however of no concern to the local commercial gardeners in the area; they'll be more than happy if they are able to pump up hot water for a few decades, Gilding and the researchers from Pan Terra maintain.
Leon Ammerlaan, a grower of tropical plants in Pijnacker-Nootdorp, confirms this. The Ministry of Agriculture has already granted Ammerlaan a 2 million euro subsidy to drill for geothermal water. "In ten years time, the land my business is on will probably be covered with newly built homes," he says. "At least that's what the municipality's development plan calls for." Long before then, however, Ammerlaan hopes to have recouped the roughly 4 million euro of his own money he has invested in the project.
But for now, Ammerlaan is biding his time. He wants more financial security. He hopes that a Guarantee Fund, which the government promised to the commercial gardeners, will be expanded. The arrangement, which has yet to be approved by Brussels, takes as its starting point the so called P90. This is the amount of energy that – with a 90 percent degree of certainty – can be generated at a particular location. Pan Terra meanwhile has calculated that there is indeed a 90 percent chance that Ammerlaan's wells will deliver at least 60,000 litres of hot water per hour.
If these wells should turn out to be less profitable than expected, the government will pay Ammerlaan the amount of money he would then have had



(INFOGRAPHIC: COURTESY NAM)

Countless numbers of tubes currently extend into the ground under Delft. Most of these drilling tube-wells were made by NAM, as it searched for oil and gas reserves in the decades following the second world war. But it will soon become a lot more crowded underground. The red lines and blue lines on the far left show the possible configuration of TU Delft's tube system. On the right are the possible positions of those from local commercial gardeners in Pijnacker. The red tubes will pump up hot water from a sandstone layer located 2.2 kilometres underground. The blue tubes will pump the cooled water back to a depth of 2 kilometres.

Photo: Sam Rentmeester/fmax

Geologist Julien Smeulders: "I encounter the strangest things"

to spend on natural gas. But Ammerlaan does have to assume 15 percent as personal risk and he must also pay a premium. "It boils down to this: I could potentially incur a loss of 660,000 euro," he concludes. "I don't have that kind of money in my back pocket. With such a guarantee in place, no one will be willing to drill."

Fossils

Tomato grower Van den Bosch isn't waiting around for a guarantee fund. He has acquired a taste for drilling for hot water. At his second nursery in Berkel en Rodenrijs, a 15 metre high drilling platform towers above a sea of greenhouses. Hundreds of drilling pipes are neatly stacked up next to a small path leading to the construction site, where workers from a German drilling company are busy preparing for the last major phase in the drilling process.

The well they have drilled so far extends downwards some 930 metres to a sandstone layer dating from the Cretaceous period, and they have only about one more kilometre to drill, but this will be through a few notoriously sticky layers of clay dating from the time when the western Netherlands was one huge swamp. Only then will they have hit the jackpot: a thick layer of Rijswijk sandstone containing 70 °C water.

"This sandstone came into existence when this area was just sea and sandy shorelines," says TU alumnus Julien Smeulders, who works as a geologist for Petrogas Minerals International, the company supervising the drilling. "It's much more equally distributed than the Delft sandstone, which reduces the chances of drilling in the wrong place. This layer does however lie a couple of hundred metres higher, so it's also not as hot, but still, 70 °C is more than enough for the greenhouses."

During the drilling, Smeulders lives in a mobile home next to the drilling platform. "The drill makes a quiet humming sound when it's going through easily penetrable earth layers. With that noise in the background, I sleep well. But as soon as the drill shudders, I'm wide awake. We then bring up samples to see what kind of layer we're drilling in and what exactly is going on below."

Although Smeulders is foremostly a mineral researcher, all the other natural history information brought to light during the drilling does make his heart beat faster.

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"I encounter the strangest things," the earth scientist says. "I've found fossils of foraminifera, small sea creatures that were never before known to be found in those stone layers. It's fantastic. You learn so much about these small creatures and the climate here at that time."

"Ultimately, we'll drill in dozens of locations in this area," Smeulders continues enthusiastically, "and later perhaps also in other parts of the Netherlands. In the eastern part of the country there are locations where you can drill into stone dating from the Carboniferous period, which began almost 300 million years ago. And in Assen we might even be able to pump up water from layers dating from the 450 million year old Ordovician period. We also know very little about these layers in the Netherlands."