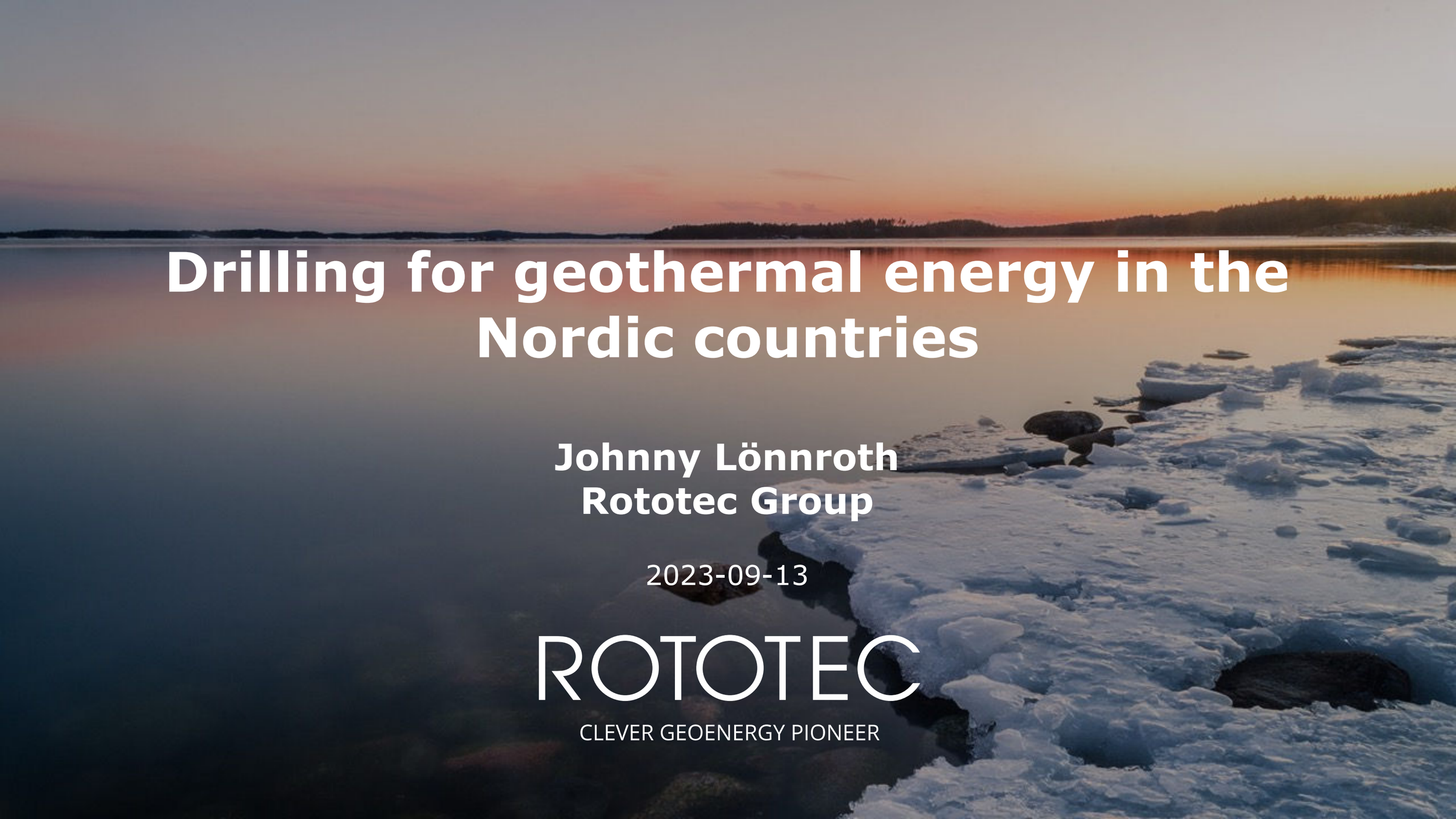


Drilling for geothermal energy in the Nordic countries

Johnny Lönnroth
Rototec Group

2023-09-13

ROTOTEC

CLEVER GEOENERGY PIONEER

Rototec as a company

0,15060976

Rototec’s team today

Johnny Lönnroth

Principal Analyst
Consulting Manager Sweden
PhD Physics, BSc Economics & Finance

- Rototec Group since 2018
- Responsible for business intelligence, market research, strategy and mergers and acquisitions
- Responsible for Rototec Consulting in Sweden
- Previous experience:
  - Management consultant at Boston Consulting Group (BCG), Finland
  - Researcher at the Joint European Torus, United Kingdom (EU’s fusion energy research centre)
- Education:
  - PhD Engineering Physics, Aalto University, Finland
  - BSc Economics and Finance, University of London

Jonas Grundström

Development Director Germany

- With Rototec Group since 2017
- Responsible for sales organisation and project execution in Sweden
- Responsible for launching Rototec’s operations in Germany
- Previously CEO and founder of geothermal drilling company Borrkronan AB
- Education:
  - BSc in community planning, Stockholm University

ABOUT US

Founded in 2007.

We deliver geothermal energy wells for ground source **heating and cooling** especially for large properties and industries and provide consulting services for geoenergy projects.

Our services range from consulting with regards to **geoenergy solutions** to ground analysis and installation.

Our presence worldwide

Nordics

USA

Germany

Market entry ongoing

ROTOTEC IN NUMBERS

2.0

Million metres of energy wells drilled per year

310 000

Tonnes/year reduction in CO_2 emissions thanks to Rototec's energy wells

58

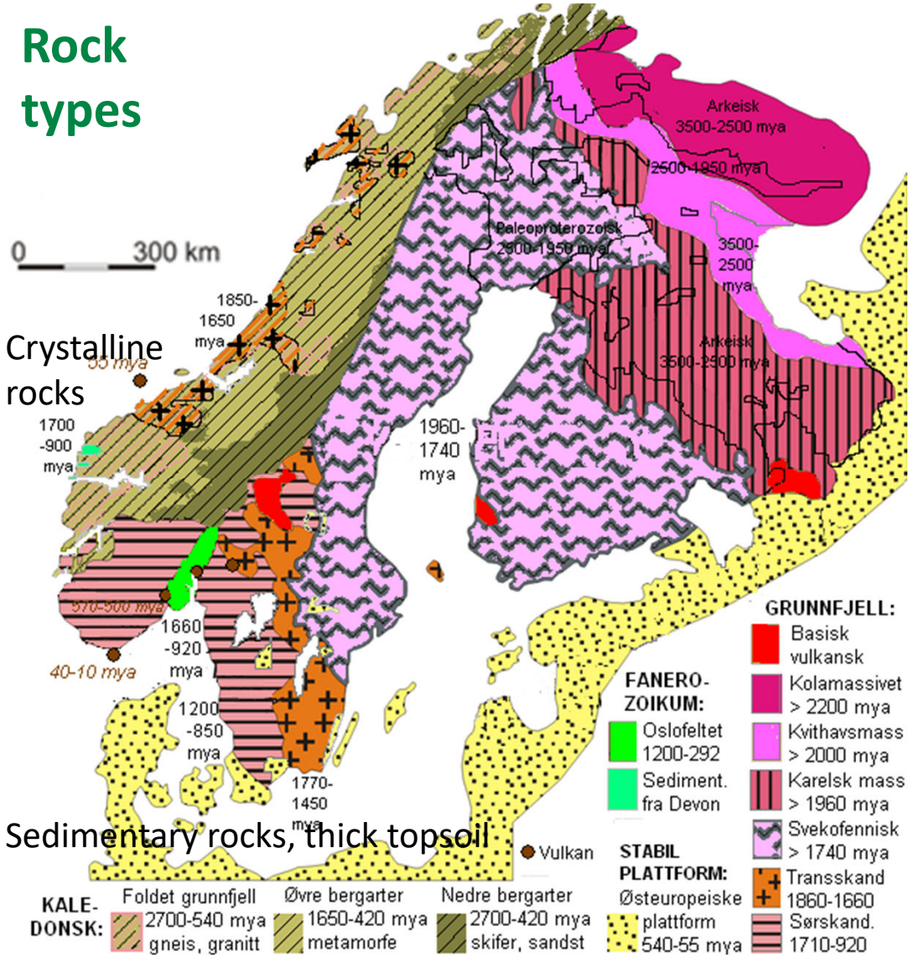
Modern drilling units

Geoenergy has an established position in a sustainable society today and in the future. By storing, and saving energy, we can save both money and environment.


Drilling in the Nordics

Geology – mostly crystalline bedrock covered by a thin layer of topsoil

Rock types



All of Fennoscandia (Norway, Sweden, Finland and the Kola peninsula and Karelia in Russia) is covered by different hard crystalline rocks. The southern tip of Sweden (Scania) and the islands Öland and Gotland feature sedimentary rocks such as limestone and sandstone.

Average soil depth is only of the order of 10 metres, although there are some areas with up to 100 metres of topsoil, notably Scania and Northern Sweden and Finland.

Soil depth

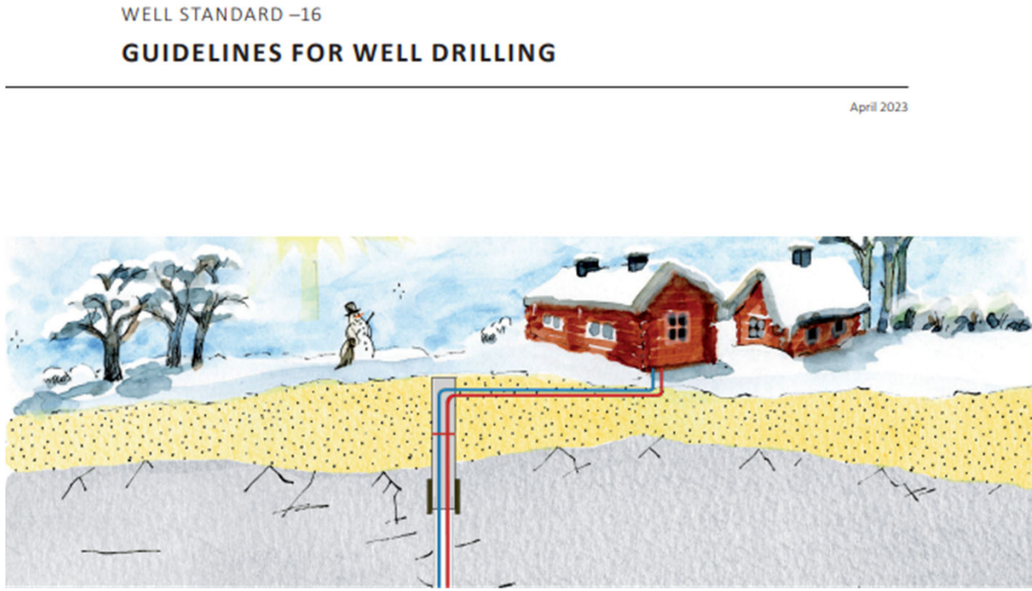
Nordic market in 2022

Country	Population (million)	Ground source heat pumps sold
Sweden	10.4	28 160
Finland	5.5	11 772
Norway	5.4	3 514
Grand total	21.3	43 446

Total market: ~ 11.7 Mm
Rototec total drilling: ~ 2.0 Mm

Permits and regulations

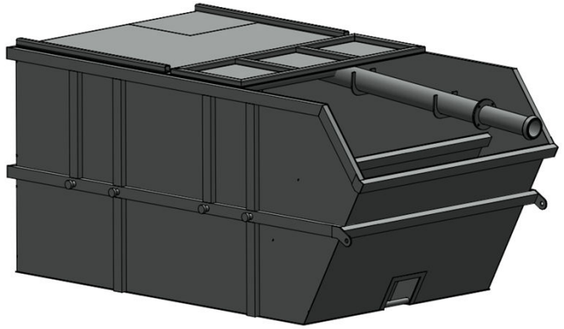
- Drillers need to be certified in Sweden, where certification is done through RISE and has three different levels: Well Driller, Responsible Well Driller and Responsible Well Driller with Welding. In Finland and Norway certification is recommended and often a specific requirement in drilling permits
- Guidelines for how to construct geothermal wells with the purpose to protect the groundwater. In Sweden, “Normbrunn-16” compiled by the Swedish Geological Survey. Many of these guidelines are followed in Finland and Norway as well
- Drilling permits for individual projects are issued by the municipalities. It is commonplace that municipalities require guidelines such as Normbrunn-16 to be followed and drillers to be certified. Drilling in groundwater protection areas is usually restricted. Grouting can be required in these areas



Drilling the Rototec way – typical for the Nordics

- Single head rig. Typically a small Comacchio or Geawelltech rig on track belts
- 35-bar compressor
- Compressor and rig transported on the same truck
- Down-the-hole hammer drilling method
- 115 mm diameter boreholes in bedrock, 139.7 mm casing in topsoil
- Casing is drilled 2 m into solid bedrock and left in the ground
- One drilling unit typically drills 300 m in one day

Cuttings and water treatment



Cuttings (stone dust) collected in a dumpster and transported to an appropriate dump site. Sediments are allowed to settle in the dumpster before water is pumped out e.g. to a storm drain.

Water treatment dumpster (Rotocont or Rotocont+): An addition to the standard process where. Water is filtered through several compartments to achieve higher levels of purity. Developed by Rototec. Patent pending.

Loop installation

Collectors and horizontal pipes installed using a slangman

Most common collectors:

- 2 x 40 mm PN10 PE100 SDR17
- 2 x 45 mm PN10 PE100 SDR17
- 2 x 50 mm PN10 PE100 SDR17

Mainly in systems with a large cooling demand relative to heating

- 4 x 32 mm PN10 PE100 SDR17
- 4 x 40 mm PN10 PE100 SDR17

When grouting usually dimension ratio SDR11

The market moved from 140 mm borehole diameter to 115 mm

Borehole diameter is not regulated in the Nordics

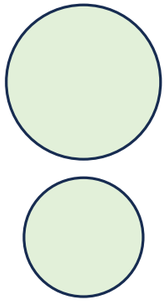
- Swedish drilling companies started to introduce 115 mm boreholes in the early 2000s
- Given significant economic advantages, the practice became widespread over time
- Rototec introduced the practice in Finland in 2007 and in Norway in 2011, whereby it quickly took hold in these countries also

In order to drill 115 mm boreholes in solid rock, we drill 140 mm casing in the topsoil and 2 m into solid bedrock. The casing is left in the ground.

Significant environmental and economic benefits with 115 mm vs 140 mm boreholes

- Lower fuel consumption
- Less cuttings (stone dust) to transport away
- Lower consumption of drilling materials (steel pipes, grout, …)
- Lower consumption of wearable parts (drill bits, hammers…)
- In some cases better thermal conductivity (borehole resistance)
- Faster drilling

Drawn to scale



140 mm

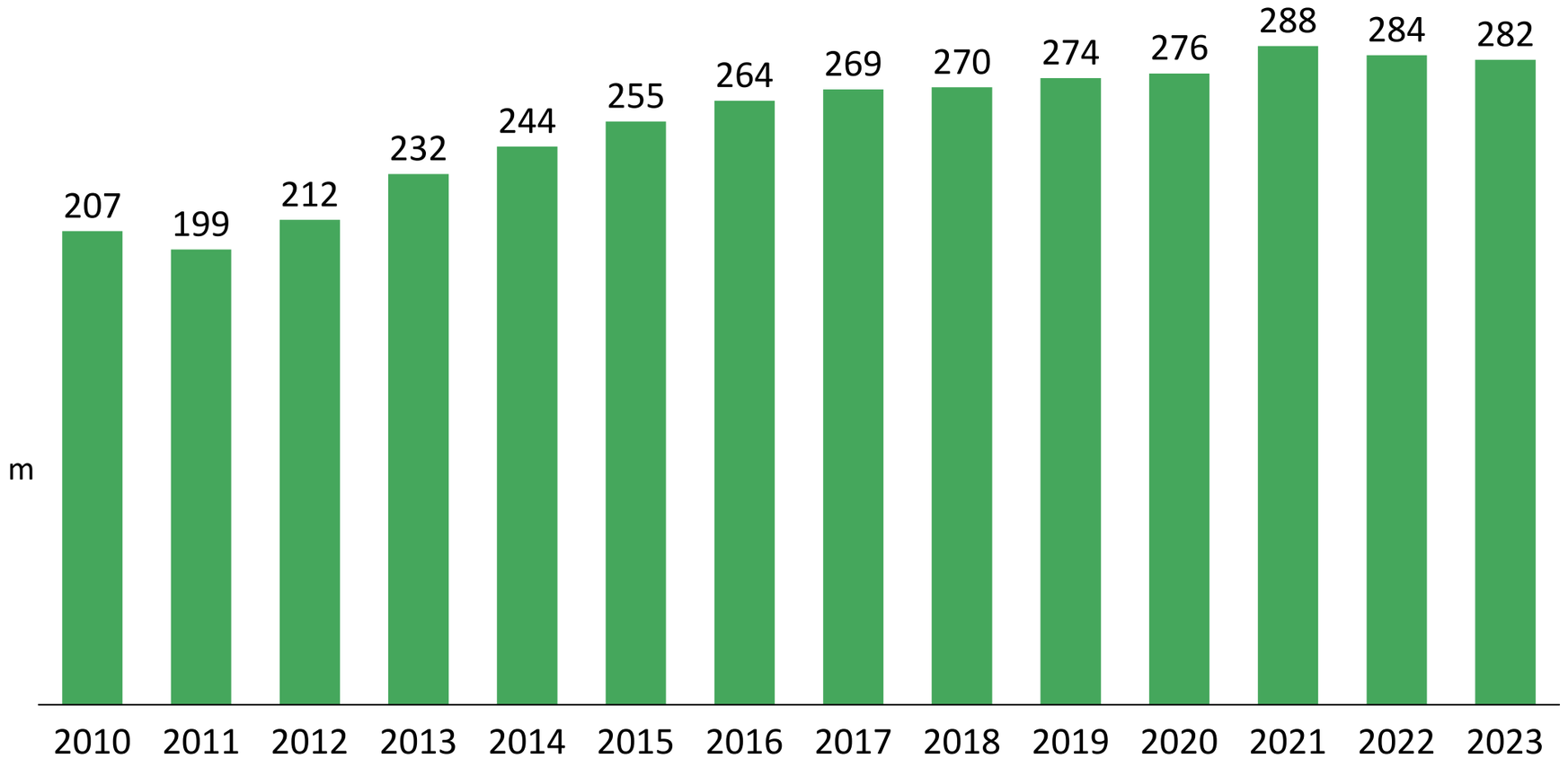
115 mm

115 mm borehole has ~ 33% less surface area

Borehole depth has also increased over time

The economic sweet spot is typically around 300 metres When drilling beyond this depth, fuel consumption starts to go up too rapidly to offset the cost of starting to drill a new borehole (which requires more casing etc)

Average depth of boreholes in medium and large projects (3 or more boreholes) drilled by Rototec



Geoenergy has the lowest running cost and emissions compared to traditional methods

Finland

Heating method	Typical running cost (c/kWh)	Emissions (CO_2 equivalent, g/kWh)
Oil	16	288
Gas	16	218
District heating	10	103
Electricity	15	60
Geoenergy	4	17

With prices forecast for a typical single-family home for the next 12 months

The electricity mix in Sweden and Norway has even lower specific emissions, whereby the geoenergy has even lower emissions in these countries

Typical payback time ~ 10 years

In Finland and Sweden, the main competing heating source is district heating. With currently forecast prices the payback time of a geoenergy installation compared to district heating is typically around 10 years


New development areas:
Deep wells
Geolo energy station
Balanced thermal networks

Deep boreholes – what and why

- Commercially viable conventional boreholes have typically been up to 400 m deep in the Nordic market. The sweet spot is around 300 m
- In densely built city centre locations, there is often not enough space for a sufficient number of conventional boreholes. Previously, geothermal energy has not been used in such locations, or it has been used in hybrid solutions only
- Using deeper boreholes makes it possible to offer full-scale geothermal solutions in such locations
- Rototec now offers 600 – 700 m deep boreholes as a commercially viable solution. Substantial demand exists for such a solution
- Rototec has developed special techniques for drilling deep boreholes

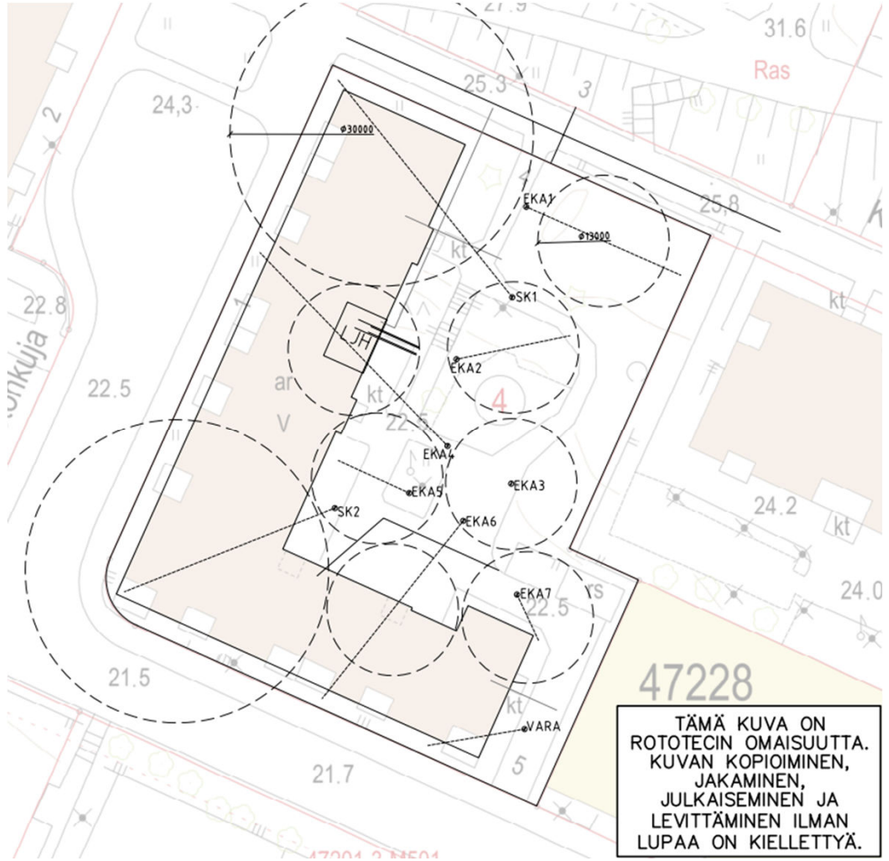
Drilling of 838-metre borehole near Tampere, Finland

Performance of deep boreholes – promising TRT analysis results

- Borehole depth: 838 m. Collector 2 x 55 mm PN10 PE100 SDR17
- Standard TRT measurement. 15 kW heating power
- No indications of significant thermal short-circuiting with a U-pipe collector, contrary to industry expectations
- Undisturbed ground temperature rising by 1.5 K/100 m
- Different brines tested: Kilfrost and ethanol. Ethanol better from a practical point of view (but lower pressure loss with Kilfrost)

Technically and economically best solution is often a hybrid of deep and standard wells

- Main purpose of shallow boreholes is to provide heating power during heating season
- Main purpose of deep boreholes is to provide a steady baseload of energy
- After the heating season, excess heat is injected into shallow boreholes for as long as the brine temperature allows it. This can be heat from the deep boreholes or e.g. from exhaust air recovery
- Usage time of deep boreholes is maximised to benefit from much larger energy reserves
    1. Domestic hot water
    2. Space heating
    3. Shallow borehole rejuvenation via heat exchanger / ground source heat pump
- Essentially the idea is to extract as much free heat as possible and use shallow boreholes as heat storage



Case example: Hybrid with standard and deep boreholes and indoor drilling

Building

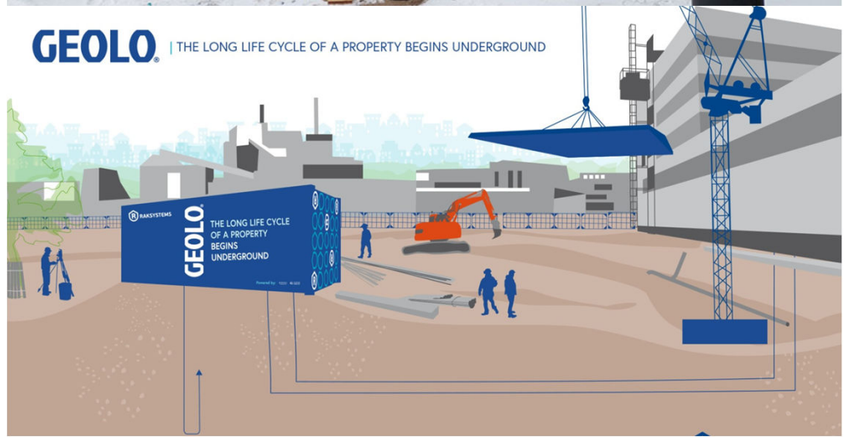
- Office building in Helsinki, Finland with small plot
- Retrofit from district heating

Geothermal solution

- **9 x 600 m deep wells**: Provide net heat 135 kW/m/year, at most 30 W/m
- **4 x 430 m standard wells**: Provide net heat 99 kW/m/year, at most 22 W/m
- **40 x 290 m standard wells drilled from the parking garage in the basement**: Used only for cooling and short peak heat loads. Provide net heat 5 kW/m/year, at most 50 W/m for heating and 68 W/m for cooling

Geolo energy station – sustainable energy during building construction

- Fully movable energy station with ground source and air source heat pumps which makes it possible to use geoenergy already during the construction phase of a building
- Contributes to reduced CO_2 emissions during the construction phase and thus during the building's entire life cycle
- Contributes to a better indoor climate already during the construction phase – reduces the potential for mould and damp to do damage
- Collaboration between Raksystems, Rototec and El-Björn

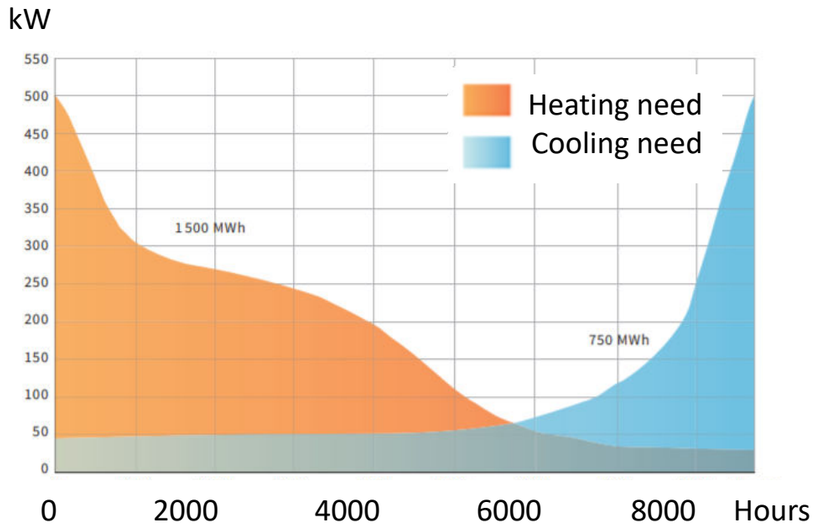


RAKSYSTEMS ROTOTEC CLEVER GEOENERGY PIONEER EL-BJÖRN

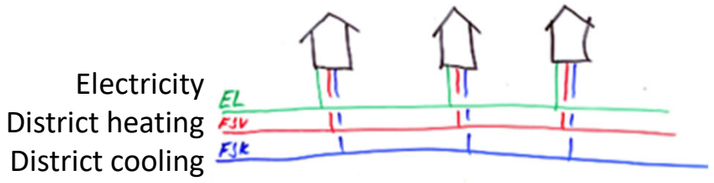
What is a balanced thermal network?

General

- Network for transferring and storing heating and cooling between buildings with different demand profiles and over daily and seasonal cycles
- Enables recycling of low-value energy
- Usually very good economics

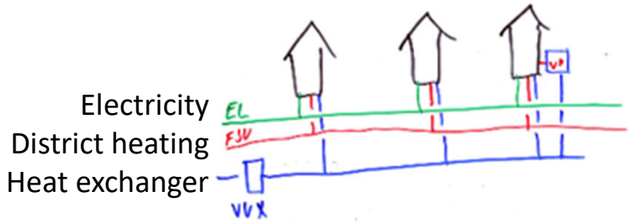


Traditional solution…



The property owner pays multiple times for energy that could be recycled: separately for electricity, heating for one part of the property, cooling for another part of the property etc.

…versus a balanced thermal network



Heating need from one building is recycled as cooling in another building and vice versa.

Case Umeå University Hospital, Sweden

Type of building complex:	Hospital
Type of project:	Retrofit
Total floor area:	345 000 m2
Type of solution:	Hybrid with geothermal, district heating and cooling , exhaust air heat recovery, air chillers and other technologies
Number of geothermal wells:	More than 200
Heating need coverage:	27 % geothermal
Cooling need coverage:	95 % geothermal
Annual savings:	1 MEUR
Yield on investment:	12 %
Main contractors:	Rototec, Energy Machines, Projekt Energi

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ProjektEnergi


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