Experiences with deep boreholes in Scandinavia

EUROPEAN SHALLOW GEOTHERMAL DAYS
9th December 2020

Jan Herranen
AGENDA

- Rototec
- Environmental politics in Nordic countries
- Drilling technique and equipment
- Geoenergy as an investments and trends in Scandinavia
- Success stories

Experiences with deep boreholes in Scandinavia
ROTOTEC

We deliver geo-energy fields for ground source **heating and cooling** especially for large properties and industries and provide consulting services for geo-energy projects.

Our services range from consulting with regards to **geo-energy solutions** to ground analysis and installation.
MISSION & VISION

**OUR MISSION** is to improve energy self-sufficiency.

**OUR VISION** is to provide the best customer experience in the energy sector.
Rototec was founded in 2007 to challenge old-fashioned ways of doing and thinking in the industry. That marked the beginning of Rototec’s path to becoming the largest geo-energy company in Europe.

The growth of the company is based on strong organic growth as well as acquisitions.

Rototec is the market leader in large properties and the preferred partner in Norway, Sweden and Finland.
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.
Rototec sites near major cities

Independent, renewable and cost-effective geo energy.

Helsinki

Tampere

Stockholm

Oslo
Geoenergy in Sweden

Over 500,000 drilled wells!
## Environmental politics in Nordic countries. Main drivers

<table>
<thead>
<tr>
<th>Country</th>
<th>Year</th>
<th>Goal/Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweden</td>
<td>2020</td>
<td>Renewables to 55% of primary energy</td>
</tr>
<tr>
<td></td>
<td>2030</td>
<td>Lower green house gases 40% compared to 1990</td>
</tr>
<tr>
<td></td>
<td>2045</td>
<td>No fossil fuels in transport sector</td>
</tr>
<tr>
<td>Finland</td>
<td>2029</td>
<td>No coal</td>
</tr>
<tr>
<td></td>
<td>2029</td>
<td>Half the usage of imported oil</td>
</tr>
<tr>
<td></td>
<td>2029</td>
<td>Renewables in transport sector to 40%</td>
</tr>
<tr>
<td></td>
<td>2029</td>
<td>No oil for heating in government buildings</td>
</tr>
<tr>
<td></td>
<td>2035</td>
<td>Carbon neutral</td>
</tr>
<tr>
<td>Denmark</td>
<td>2025</td>
<td>Copenhagen. World's first carbon neutral capital</td>
</tr>
<tr>
<td></td>
<td>2030</td>
<td>No coal</td>
</tr>
<tr>
<td></td>
<td>2030</td>
<td>No oil for heating</td>
</tr>
<tr>
<td></td>
<td>2050</td>
<td>No fossils used</td>
</tr>
<tr>
<td>Norway</td>
<td>2020</td>
<td>Heating oil ban</td>
</tr>
<tr>
<td></td>
<td>2030</td>
<td>Carbon neutral</td>
</tr>
</tbody>
</table>
238 890 000 kg less CO² per year
208 274

One-way flights from Helsinki to Bangkok
DRILLING TECHNIQUE AND EQUIPMENT

Down-the-hole (DTH) drilling
139,7 x 5,0 mm permanently installed steel casing pipes > 2 meters into bed rock. Soil depth 0-100m in Scandinavia.

114,3 mm drilling in bed rock.

Camacho MC 450 drilling units

Atlas Copco DrillAir Y35, (35 bar) compressors. If >500 meters possible need for booster.

12 m, 4 axel truck, for transportation of the full equipage.

Streamlined processes, high flexibility and quick mobilization ensures ~300m/day/unit.
Geoenergy as an investment in Skandinavia

Geoenergy investment is approximately **30–70 €/m2** (1-2% of total cost).

Larger system is **more cost efficient**.

Return of investment varies from **6 to 20%** depending on project.
Rising energy prices will increase the savings from geoenergy

The price of district heating has doubled since 2001 and will continue to rise.

The savings brought by geo-energy will increase with the rise in energy prices.

- District heating
- Electricity
- Geoenergy
- District heating trend
- Geoenergy trend
Example: Social and health care center in Järvenpää. Heated area (m²) 13 500 and 49 x 310m wells

<table>
<thead>
<tr>
<th>Investment cost (EUR)</th>
<th>2017</th>
<th>2018</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geoenergy + peaks with district heating (realized investment)</td>
<td>1 090 000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alternative investment: district heating + water cooling machines</td>
<td></td>
<td>470 000</td>
<td></td>
</tr>
<tr>
<td><strong>Difference</strong></td>
<td></td>
<td><strong>620 000</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Price for energy consumed(EUR)</th>
<th>2017</th>
<th>2018</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative investment: district heating + water cooling machines</td>
<td>166 829</td>
<td>174 980</td>
<td>170 905</td>
</tr>
<tr>
<td>Geoenergy (realized cost)</td>
<td>79 795</td>
<td>86 652</td>
<td>83 224</td>
</tr>
<tr>
<td><strong>Saving</strong></td>
<td><strong>87 034</strong></td>
<td><strong>88 328</strong></td>
<td><strong>87 681</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Power consumption(MWh)</th>
<th>2017</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating</td>
<td>2 335</td>
<td>2 346</td>
</tr>
<tr>
<td>Cooling</td>
<td>522</td>
<td>697</td>
</tr>
</tbody>
</table>

The payback period for the additional investment will be 7.1 years with the average savings realized so far. Yield 14.1% / year without considering a future increase in energy prices.
Excellent conditions for the utilization of geo-energy in the Nordic countries

Fennoscandia (Finland, Sweden, Norway)
- Suitable bedrock for making boreholes
- Cold climate => High heating needs
- Cheap electricity for running heat pumps
- Favorable laws, regulations and environmental policy
- The use of geoenergy based on shallow wells is very economically viable
- Sweden, Finland and Norway are pioneers in the use of geoenergy

Island
- Mainly deep geothermal systems: Hot water is pumped directly from so-called “hot spots”

Denmark
- Sedimentary bedrock under a deep topsoil => Lots of horizontal systems. Also, deep geothermal systems
  - A milder climate
  - Expensive electricity
Sweden is the world's leading country in the use of geoenergy

<table>
<thead>
<tr>
<th></th>
<th>Sweden</th>
<th>Finland</th>
<th>Norway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground source heat pumps in use</td>
<td>580 000</td>
<td>150 000</td>
<td>55 000</td>
</tr>
<tr>
<td>Increase in the number of GSHP in 2017 - 2018</td>
<td>4.3 %</td>
<td>6.8 %</td>
<td>10.9 %</td>
</tr>
<tr>
<td>Geoenergy systems per 1000 inhabitants</td>
<td>55</td>
<td>22</td>
<td>8</td>
</tr>
<tr>
<td>Total power of geoenergy systems</td>
<td>6500 MW</td>
<td>2500 MW</td>
<td>1000 MW</td>
</tr>
<tr>
<td>Energy produced by geoenergy (including pumped electricity)</td>
<td>23 TWh</td>
<td>6 TWh</td>
<td>4 TWh</td>
</tr>
</tbody>
</table>

Source 2018: European Geothermal Energy Council, Svenskt Geoeenergicentrum, Sulpu
Each country has its own characteristics

**Sweden**
- Leading country in the world in geoenergy utilization. Systematic effort since the 1970s: Sweden was the largest oil importer per capita. The country already had drilling and refrigeration technical know-how
- About 10% of systems use non-boreholes (land and water circuits and open systems)

**Finland**
- About 50% of new detached houses choose geothermal as a form of heating. The largest share in the world

**Norway**
- The ban on the use of heating oil, which will enter into force at the beginning of 2020, has boosted the geoenergy market in all size categories

In all countries:
- Economy is the main selection criterion, but environmental values are becoming increasingly important
- Installations in large properties are becoming more common
The Nordic district heating properties will be transferred to geoenergy or merged to geoenergy hybrid systems for several reasons.

### Geoenergy

<table>
<thead>
<tr>
<th>Built - in synergies</th>
<th>District heating and district cooling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling is obtained without additional investment and improves system performance</td>
<td>District heating and district cooling are separate systems without major practical synergies</td>
</tr>
<tr>
<td>Works well with other energy sources, such as waste heat. The technologies of the future are thus easy to integrate</td>
<td>Can be combined to some extent with other energy sources, such as geoenergy</td>
</tr>
<tr>
<td>The system is robust because there is no so-called. “Single point of failure” and energy is locally produced</td>
<td>Produced centrally and delivered through a long piping system</td>
</tr>
<tr>
<td>The owner manages the production of his own energy and how he adapts this for future needs. Independence from energy prices</td>
<td>Tariffs are largely set by the district heating company</td>
</tr>
<tr>
<td>Most of the energy is renewable energy from the country. Very low climate impact especially if using certified electricity</td>
<td>Depends on the fuel. Low environmental impact when using biofuels or industrial waste heat</td>
</tr>
<tr>
<td>High investment cost, but usually the lowest life cycle cost</td>
<td>Prices vary widely between different companies</td>
</tr>
</tbody>
</table>

**Economy is usually the main criteria**
**Trend: average well depth**

**Average depth very large BHE per country**

<table>
<thead>
<tr>
<th>Average of DrillMeters</th>
<th>Column Labels</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Row Labels</td>
<td>Finland</td>
<td>Norway</td>
<td>Sweden</td>
<td>Grand Total</td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td>228,99</td>
<td>265,82</td>
<td>250,73</td>
<td>246,10</td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td>282,97</td>
<td>243,76</td>
<td>253,07</td>
<td>262,04</td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td>281,66</td>
<td>251,06</td>
<td>265,97</td>
<td>268,44</td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td>310,61</td>
<td>258,11</td>
<td>289,58</td>
<td>285,07</td>
<td></td>
</tr>
<tr>
<td>2018</td>
<td>296,60</td>
<td>273,95</td>
<td>266,62</td>
<td>281,74</td>
<td></td>
</tr>
<tr>
<td>2019</td>
<td>270,61</td>
<td>305,57</td>
<td>279,11</td>
<td>283,99</td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td>294,89</td>
<td>276,39</td>
<td>292,27</td>
<td>289,72</td>
<td></td>
</tr>
</tbody>
</table>
Future trends are already visible

**Hybrid Solutions**
Geoenergy combined with several other heat sources e.g., solar collectors, exhaust air heat pumps, bio-oil, district heating, waste heat...

**Deeper wells**
In city centers, drilling even deeper economically in the near future (about 600 - 800 m) when there is a lack of space and technology becomes cheaper

**Borehole thermal energy storage (BTES) systems**
Seasonal heat is stored in borehole storages, for example from waste incineration plants and industrial waste heat sources
Development project: Positive energy buildings utilising 600 – 1000 m deep wells

- Rototec involved in a Finnish consortium developing a positive energy building concept (buildings producing more energy than they use)

- Pilot project involving the construction of two blocks of flats in the Kalasatama district in Helsinki

- Semi-deep (600 – 1000 m) geothermal wells an essential part of the pilot project due to lack of space for shallower wells

- Rototec’s aim is to make 600 – 1000 metre deep wells a commercially viable product. This involves developing cost-efficient drilling techniques and a collector suitable for such depths

- The deep well product will be marketed as a solution for dense city centre locations. Substantial demand exists for such a solution
References with deep boreholes.

SHOPPING MALLS

HOSPITALS

OFFICE BUILDINGS

SPA & SWIMMING HALLS

INDUSTRY & WAREHOUSES

APARTMENT HOUSES
Manglerudjordet Borettslag in Norway 68 x 300m

- Size: 501 apartments
- Savings: 200 000 €/year\(^1\)
- Status: started operation in 2018
- Life cycle profit: 2,2 M€\(^1\)

\(^1\) Estimation based on available data
DN-house in Stockholm 85 x 300m

- Well known office building built for Dagens Nyheter, daily newspaper in Sweden
- 26 floors. 85 x 300 energy wells drilled in basement.
- Built in the beginning of 1960’s
- Used district heating and cooling until 2014
- From 2015: Geoenergy system installed replacing ~75% of district heating and cooling

“Thanks to this investment we do not need to buy cooling anymore and the amount of district heating used has decreased by 75% as we are using energy from the ground.”

Alexander Carlsson, Works Superintendent, Fabege
Norrlands Universitetssjukhus in Sweden

- Size: 330 000 m²
- 125 x 250m
- Savings: **450 000 €/year**
- Status: operational since 2010/2016
- Life cycle profit: 14,5 M€

“We save approx. 4,5 million kronor per year by heating and cooling with geo energy. We can use this money in health care instead.”

_Hans Johansson, Property Manager, NUS_
Sokos Hotel Break Koli in Finland

- Energy savings 1218 MWh/annually and savings in CO2 emissions 326t/annually
- Energy wells 35, depth **312 meters**
- 20 000 liters less oil in two months
- Room specific cooling system was also built during project. Cooling was taken in use even before heating solution was ready. Cooling costs next to nothing to the owner.
- Efficiency of cooling even COP 20

"The result is worthy of our National Park and cooperation has been fantastic."

**Kyösti Tuhkalainen**, Specialist, Metsähallitus (National Board of Forestry)
Shopping Center Skanssi, Turku

- 95,000 sq meters and over 90 shops
- Drillings were started in August 2018 and project took half a year
- Project included consulting, two TRT’s and drilling (112 x 350-meter wells)
- The first shopping Centre in the Europe which has received the highest **Platinum level LEED certification also during construction**. Chamber of Commerce award in 2019 which was based on sustainability.

“Good preparations and find the right partner had significant impact on the project’s success. Transfer into the new energy form has gone very well and the shopping centre has not suffered any distraction during the project”, tells Shopping Centre Skanssi’s Director **Maarit Hurme**.
Thank you!

Jan Herranen
Country Manager
Rototec Oy

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