NORM and Geothermal Projects in Greenhouse Horticulture

NORM an unexpected? encounter

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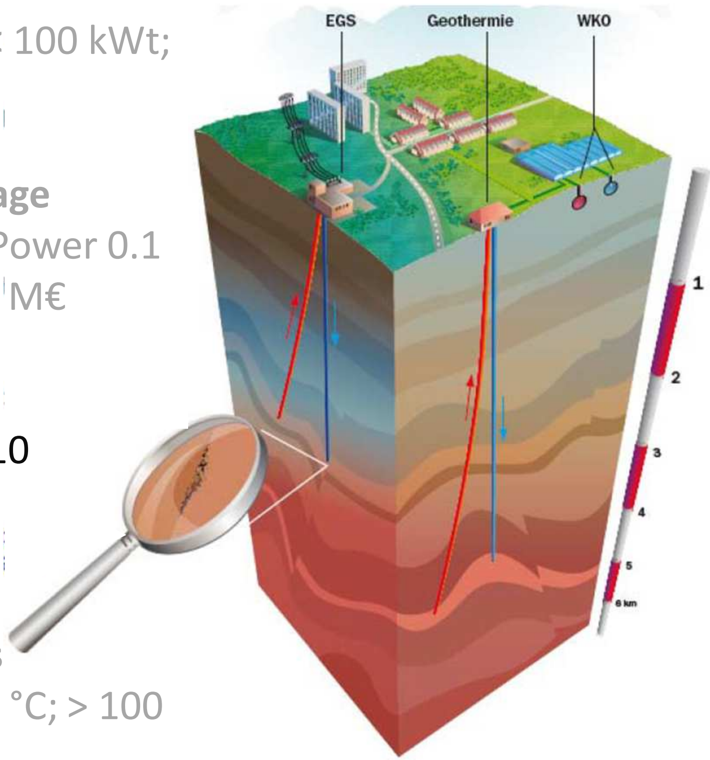
Dutch Geothermal Family

Ground Source Heat Pumps (GSHP)
Horizontal or Vertical (< 100 m); Limited Power < 100 kWt; 1000's installed, individual houses

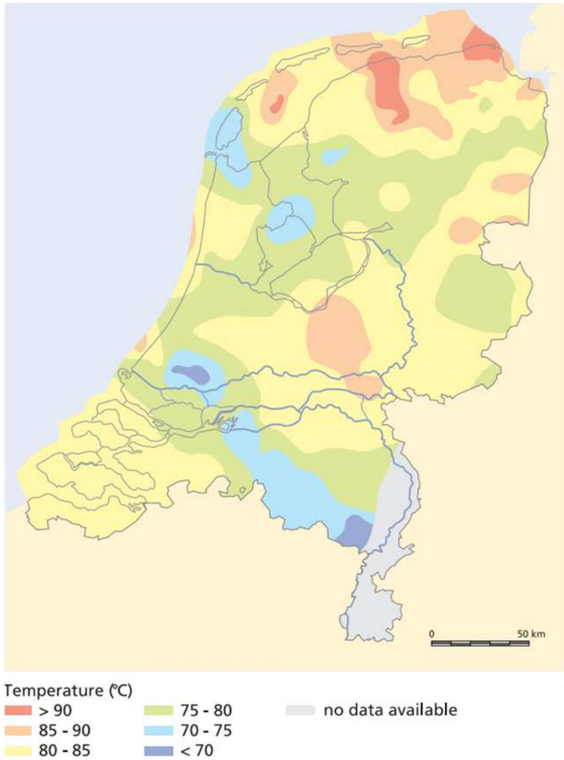
Heat Cold Storage Aquifer Thermal Energy Storage
"Shallow" Aquifers; up to 250 m (T = 5 – 30 °C); Power 0.1 – 10 MWt; ~1000 installed (offices mainly); 1 – 3 M€

'Deep' Geothermal Energy (direct use)
Doublets, Depths from 1000 m (T from 40 °C); ~10 installed 5 – 20 M€

'Ultra-Deep' Geothermal Energy Systems (Enhanced Geothermal Systems)/Hot Dry Rocks
Depths from ~3500 m; Temperatures from ~ 100 °C; > 100 M€



Dutch Geothermal Potential
Benefits & Appraisals (1)



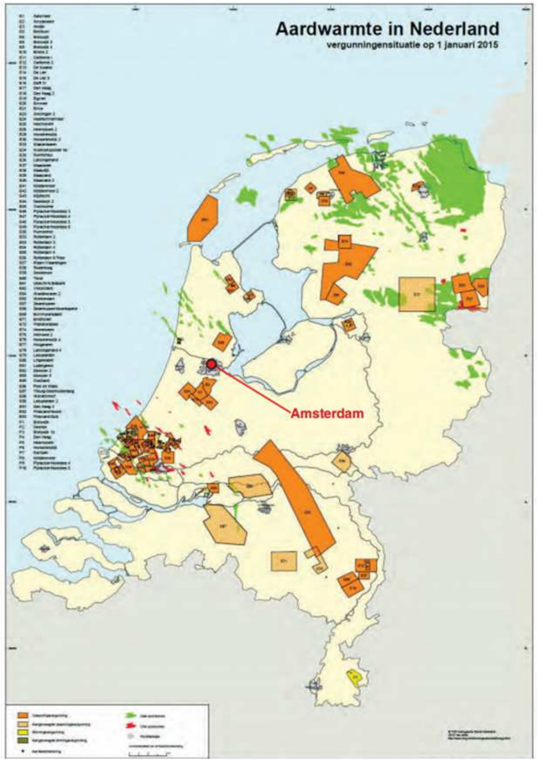
Geothermal energy (future renewable energy strategies)

- unobtrusive
- emission free
- available 24/7
- operational costs are low and stable

1987 first geothermal test not successful: several targeted aquifers from 850-1700 m yielded water with a temperature of 54 °C, too low for heating of greenhouses

2007 on initiative of a private greenhouse farmer a geothermal well was drilled: sufficient heat

Dutch Geothermal Potential
Benefits & Appraisals (2)



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2007 on initiative of a private greenhouse farmer a geothermal well was drilled: sufficient heat, but also oil and gas was produced (authority issue)

issues solved and more HSE measures were required in next drilling operations

Energy Consumption & Generation
the Netherlands (2010 data)

the Netherlands consumes 3,500 PJ/year

- 38% heating with T > 100 ^{o}C,
- 30% heating & cooling with T < 100 ^{o}C,
- 20% transport, and
- 12% electricity.

Dutch energy demand generated by combusting fossil fuels.

- 9.1% Coal
- 37.2% Oil
- 47.1% Natural Gas

remainder nuclear power and renewables (3.8%)

90% of the total heat demand provided for Natural Gas

Geothermal Energy
Barriers to deployment

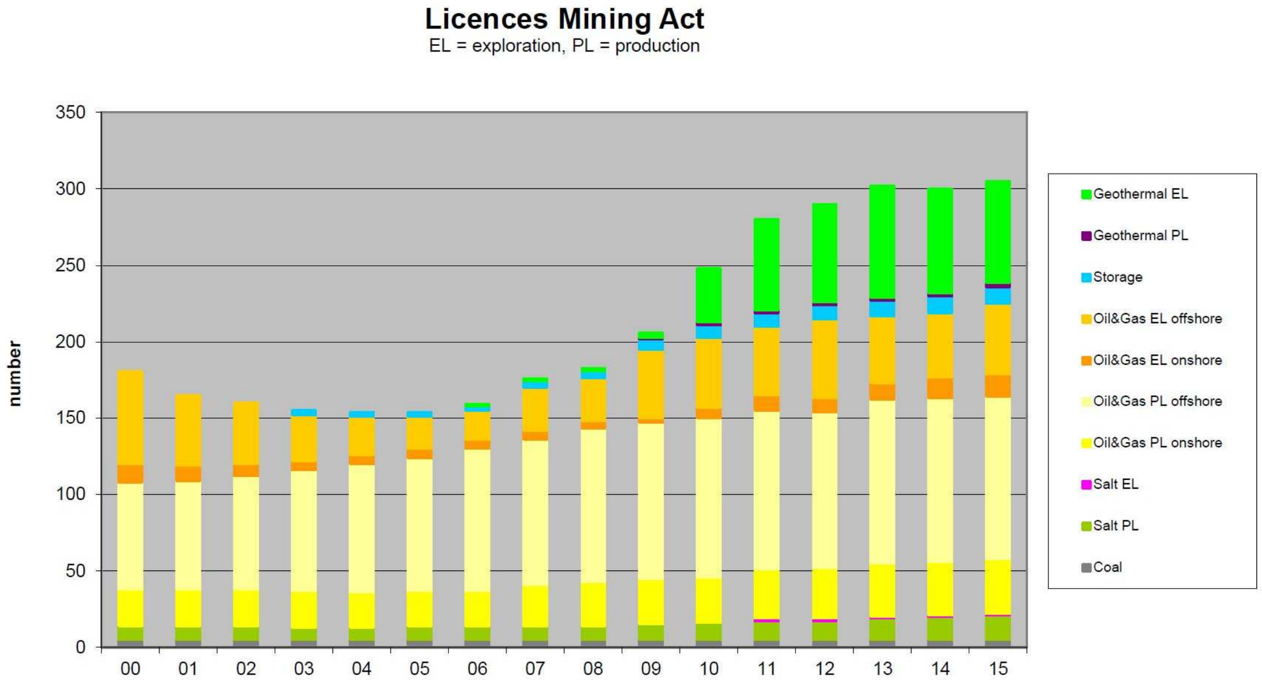
- **high up front cost of installation**
- lack of investor awareness
- existing infrastructure constraints
- landlord/tenant incentive splits
- affordable gas and oil supplies
- separate, well developed electricity and fuel delivery infrastructure
- **wealth of the Dutch gas resources**
- **tariff structure imposed on gas for agricultural application**
- lack of subsidiary instruments for the use of green heat

but under pressure of the ratified Kyoto protocol to reduce CO_2 emission, where horticulture was the largest consumer of natural gas, geothermal energy/heat production was on the radar screen again

Increase in Renewables (Geothermal Projects)

Reduction in carbondioxide emission

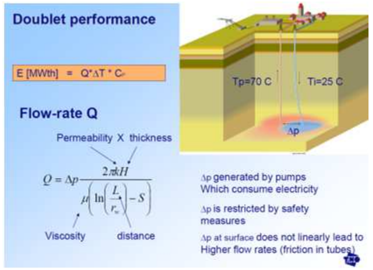
Horticulture: transition from burning natural gas (incl. CO_2 fertilisation) to geothermal heating with burning of the additional gas production



Geothermal Market Needs

Help Out

- ➢ geological properties and uncertainties
- ➢ independent analysis ad information
- ➢ overview potential areas and ‘hot spots’
- ➢ performance assessment
- ➢ economic feasibility

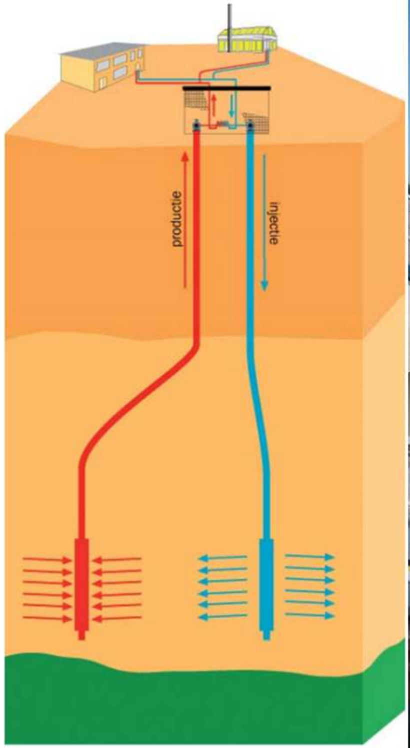


TNO has developed a web-based information system, ThermoGIS, to stimulate the development of geothermal energy from natural resources in the subsurface:

- data from pre-drill resources oil/gas industry, coal bed methane, shale gas, CO_2 storage
- geological properties (seismic data)
- dynamics of prospective aquifers
- fault zones

despite all these processed data often the flow rates achieved were lower than expected, so next to this geochemical modelling required

Geothermal Doublet
Schematics & Practice



Process Scheme for Geothermal Heat Production

Geochemistry – hot water coming up (producer):

- hot brines (T = 90 -100 ^{o}C) in chemical equilibrium with rock forming minerals

Process chemistry - gas removal, change in pressure, temperature

- dry CO_2 is not corrosive, but CO_2 in combination with water creates an acidic environment > corrosion of iron pipe work > pH decreases to ~ 5.5
- at the iron/liquid interface, an anodic reaction oxidizes Fe according
  $Fe(s) + CO_2 + H_20 \text{->} Fe^{2+} + 2HCO_3^- + H_2$
- P and/or T changes solubility product of scale forming minerals – suspended/deposited particles (baryte $BaSO_4$, galena PbS, laurionite Pb(OH)Cl)

Geochemistry – cooled water going down (injector):

- decreasing injectivity due to scaling near the perforation (blocking),
- decreasing injectivity due to particle accumulations (plugging)

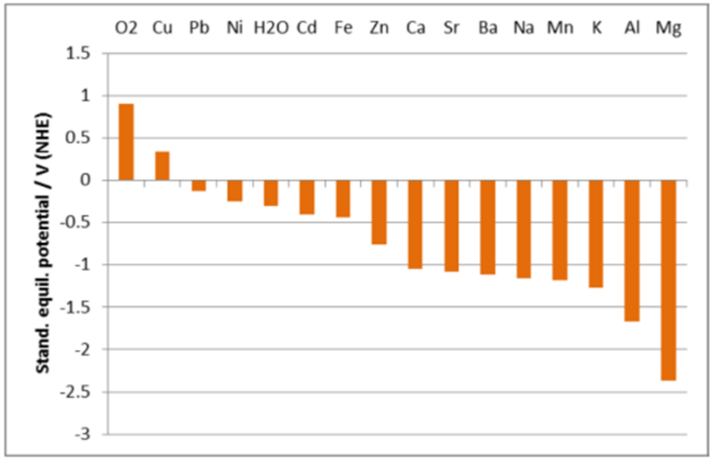
but dependent on the elemental composition of the hot brine …

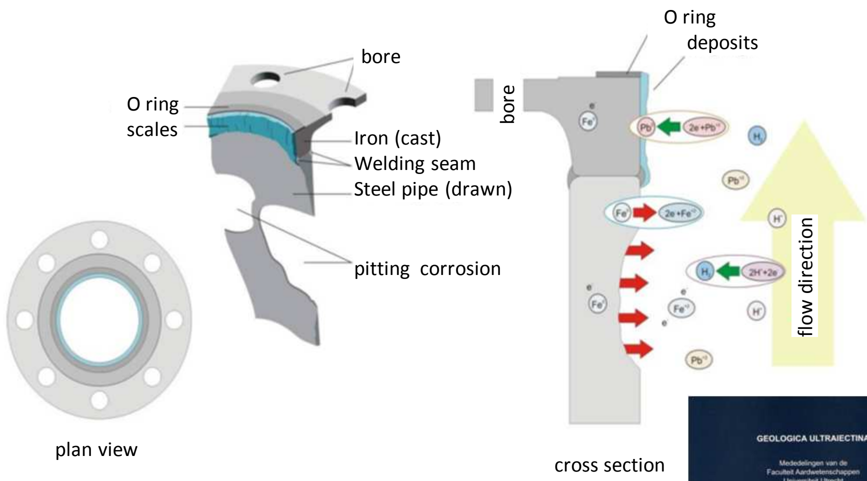
- formation of elemental lead contaminated with ^{210}Pb

Protection of the Injection Well

Deposition of metallic lead contaminated with ^{210}Pb

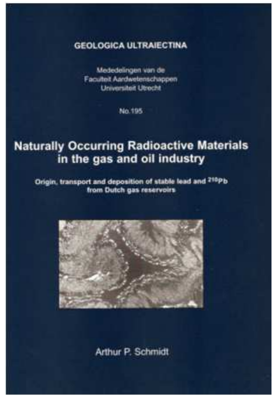
A.P. Schmidt – NORM in the Gas/Oil Industry (Ph D Thesis Utrecht University)





thermodynamically Pb^{2+}-ions are able to oxidize metallic Fe via a so-called exchange reaction. The more noble metal (Pb) is deposited and the lesser noble metal (Fe) is dissolved according to

$$Fe(s) + Pb^{2+} \rightarrow Pb(s) + Fe^{2+}$$



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Save-the-date: June 4-8, 2018.
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Thank You

Q&A

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