Aquifer thermal energy storage: Mitigation and adaptation in cities

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KWR Watercycle Research Institute

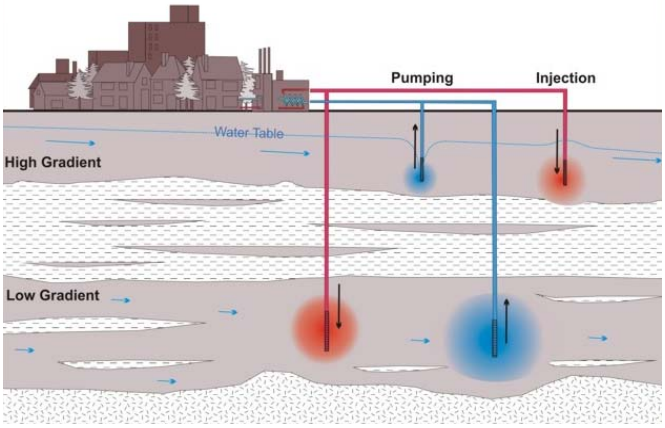
Key messages

ATES is a sustainable form of heating and cooling:

- Mitigation: ~3 Mton CO_2/yr in the Netherlands (11%)
- Adaptation: provide heat relieve in cities
- Important research questions:
  - How can we achieve the full potential or ATES?
  - What are the risks for other groundwater users?

What is Aquifer thermal energy storage?

Open loop systems



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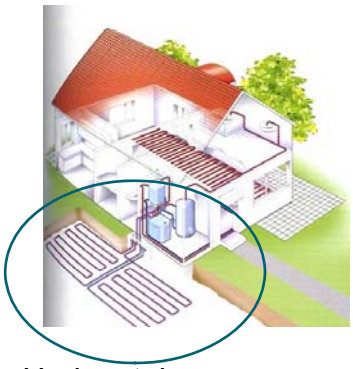
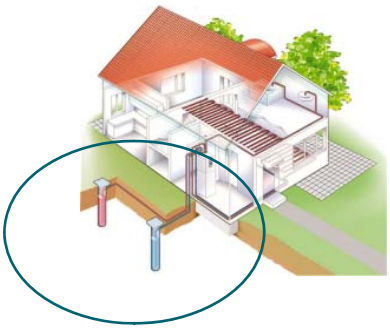
What is Aquifer thermal energy storage

Closed loop systems



Horizontal



Vertical

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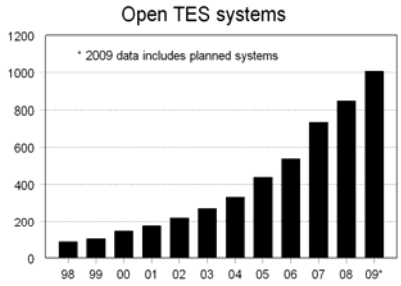
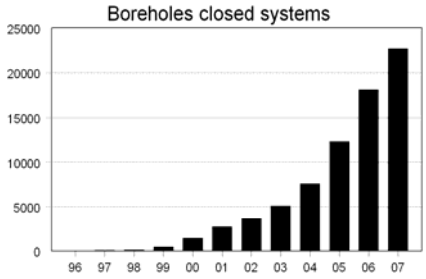
Developments in the Netherlands





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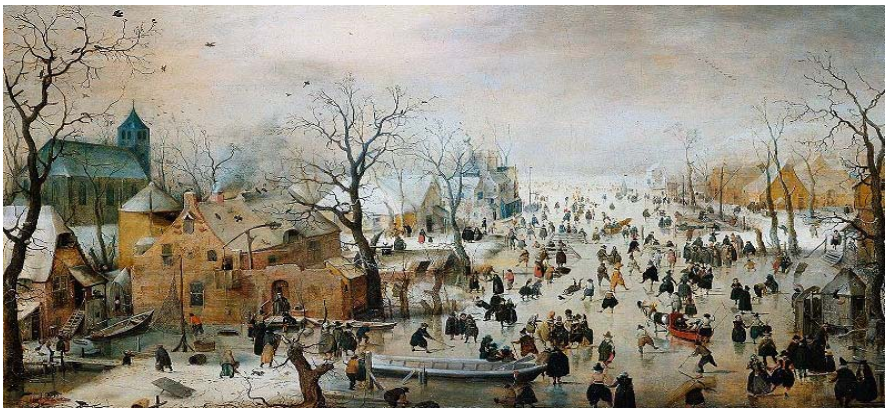
ATES and climate adaptation



Source: Hendrick Avercamp, 1608

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ATES and climate adaptation

Acclimatisation in Dutch houses mostly natural gas heating

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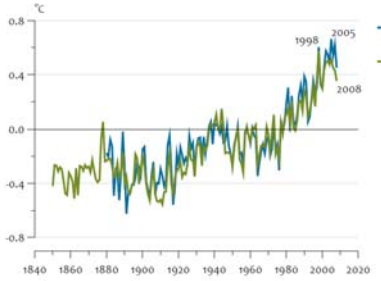
Increasing temperature + urban heat islands = more cooling requirements



ATES is especially (cost) effective in cooling mode!

Source: PBL/KNMI/WUR (2009)

Source: NASA Observatory (2009)

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Why bother about adaptation?

The Chicago Heat Wave, 1995

- 6 day heat wave, max 41°C
- UHI increased night temperatures by ~ 2°C (26 °C)
- 692 deaths (26% mortality displacement)
- Mostly poor elderly without A/C
- More deaths than all other natural disasters

(Source: Wikipedia & Eric Klinenberg, *Heat Wave: A Social Autopsy of Disaster in Chicago*)

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ATES and climate change mitigation

Open loop systems

- Energy ↓ = 8 MJ/m^3 …… 820 TJ/yr
- CO_2 ↓= 0.5 kg CO_2/m^3 ……56 kton/yr
- 0.07% in the built environment

Closed loop systems

- Energy ↓ = 870 MJ/well/yr ……. 20 TJ/yr
- CO_2 ↓= 60 kg CO_2/well/yr…… 1.4 kton/yr
- Reduction < 0.01% with >20.000 well points

(Source: If technology, 2007 & CBS, 2009; CBS, 2008)

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Estimated CO_2 reduction potential

Ministerial Taskforce ATES, 2009:

-Aim is a growth rate of 30% / year

-Energy savings: 41 PJ

-CO_2 reduction: 2.9 Mton in 2020

-11% of direct energy use in built environment (28 Mton)

ATES is not 'the' solution but part of the puzzle

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Groundwater claim

- Current ATES groundwater use:	350 Mm^3/year
- 2020 use at desired growth:	5 - 6 Gm^3/year
- Total groundwater extraction:	1.5 Gm^3/year
- Annual groundwater recharge:	9 Gm^3/year

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ATES to be largest groundwater user in 2020!

Research questions:

- How can we achieve the full potential of ATES?
- What are the risks for other groundwater users?

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Maximising the benefits (1)

Minimising interference through subsurface planning…

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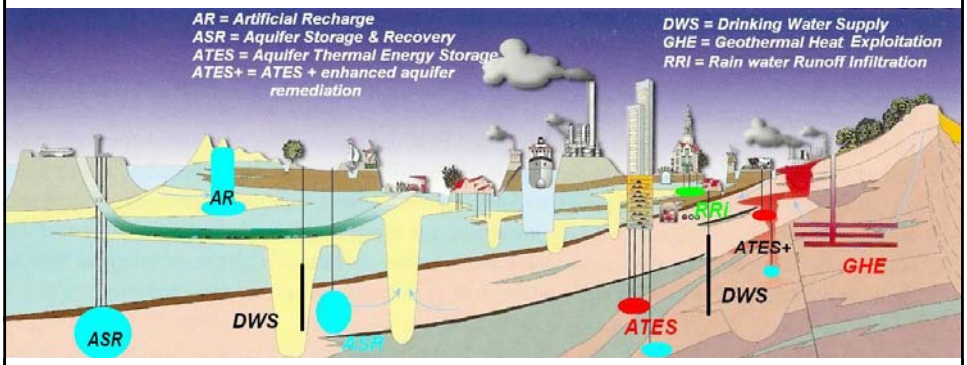
Maximising the benefits (2)

…. also with other subsurface users



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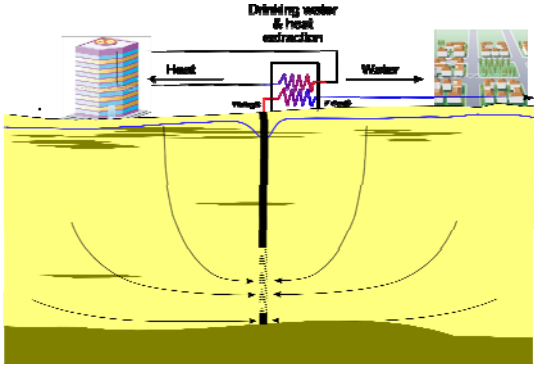
Maximising the benefits (3)

Combine water supply and heat delivery



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Minimising the risks

Effects:

- Thermal pollution
- Leaking bores, poorly sealed boreholes
- Microbiological changes
- Chemical changes
- Leaking anti freeze at closed loop systems

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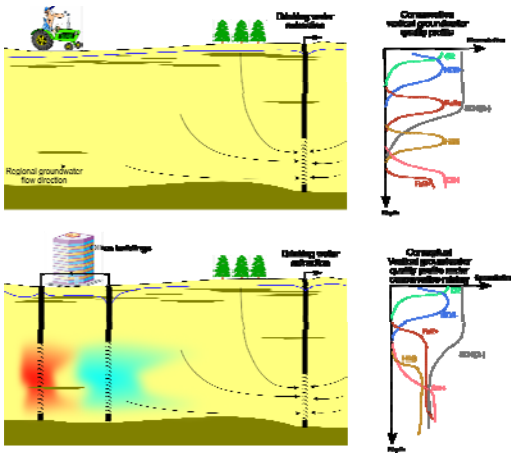
Effects of mixing in an ATES system



Vertical mixing of:

- Redox gradients
- Salinity gradients
- Shallow pollutants
- …..

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Decreasing groundwater quality increases energy use water cycle

Effects on energy use at treatment:
-'Clean' groundwater ≈ 1 - 2 MJ/m3;
- Organic pollutants ↑ → add UV/H2O2 → ~ 0.5 – 2.5 MJ/m3
- Salinity ↑ → add MF → ~2 – 6 MJ/m3

remembering: energy ↓ ATES ~ 8 MJ/m3

Clean groundwater saves energy !

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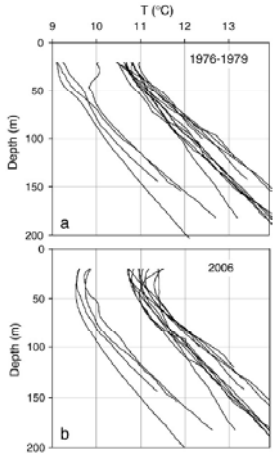
Effect increasing soil temperature on ATES



(Source: Kooi, 2008 EPSL)

-Increasing temperature penetrates aquifer to 60 m in 28 years

-Agriculture to urban → ΔT= 1.9°C

-Effect on cooling capacity of ATES?

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On going research projects at KWR

-Water Industry Research program:
effects of ATES on groundwater quality

-Ministry of spatial planning and environment:
guidlines for subsurface spatial planning

-Water and energy relations in the water cycle (Jan Hofman)

Questions

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