

# Is Heat a Contaminant?

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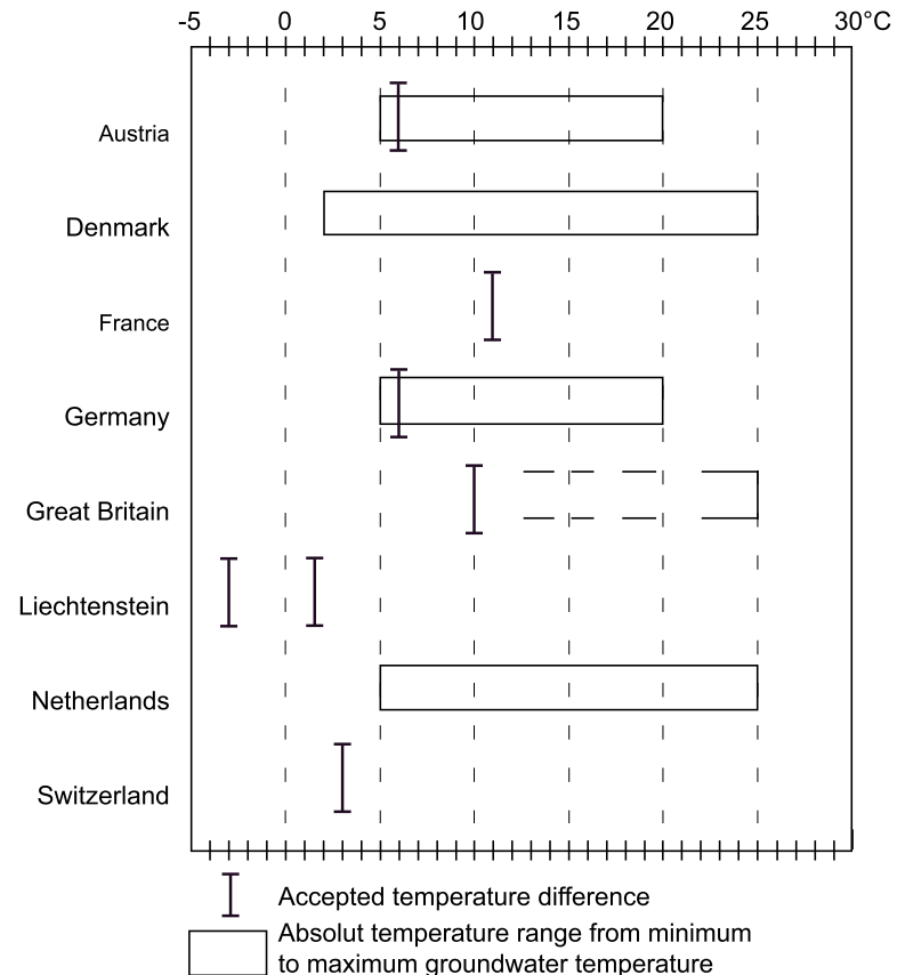


# No uniform international legislation!

## Definition

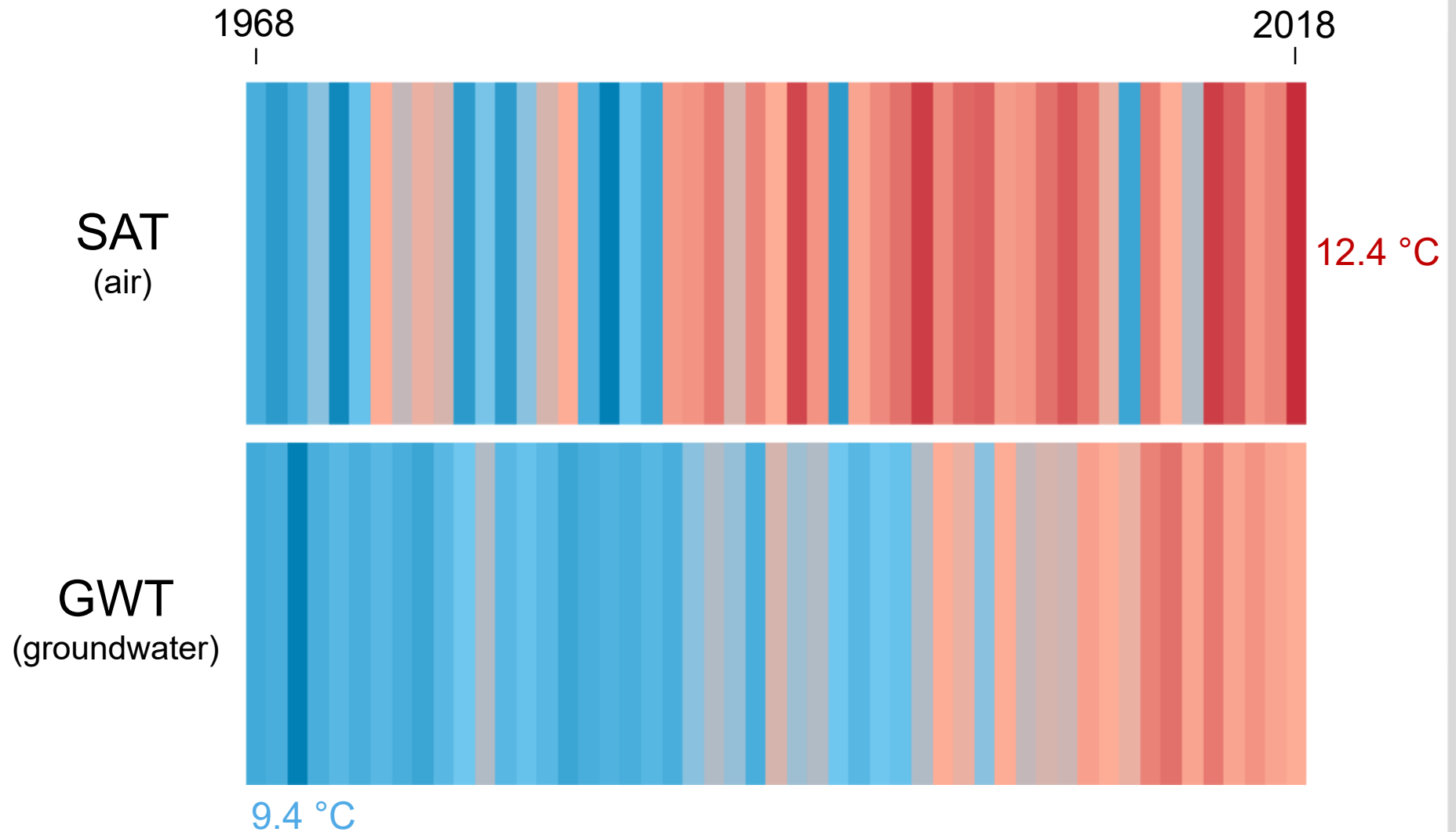
### ► EU Water Framework Directive, Article 2 (2000):

33. 'Pollution' means the direct or indirect introduction, as a result of human activity, of substances or heat into the air, water or land which may be harmful to human health or the quality of aquatic ecosystems or terrestrial ecosystems directly depending on aquatic ecosystems, which result in damage to material property, or which impair or interfere with amenities and other legitimate uses of the environment.



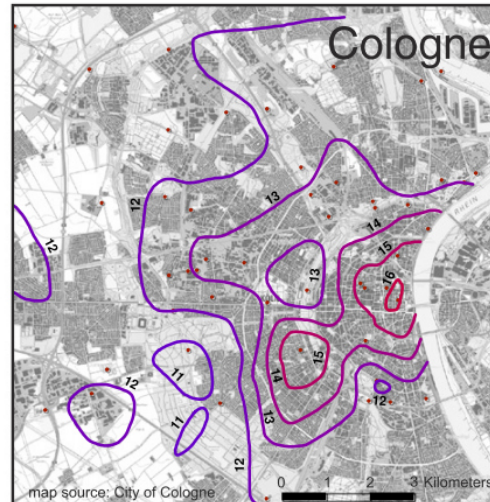
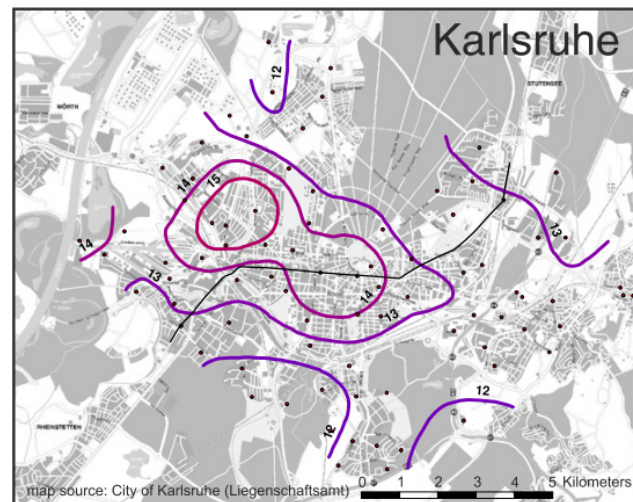
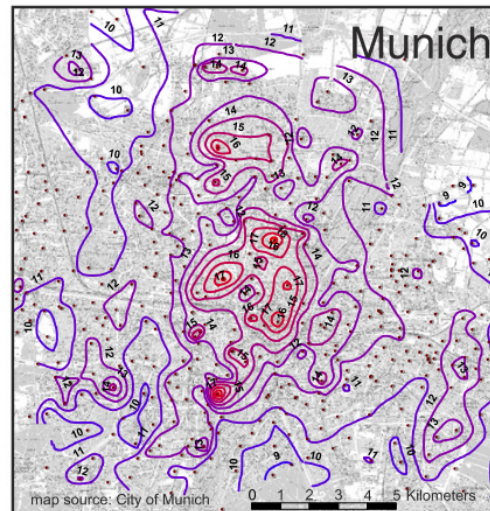
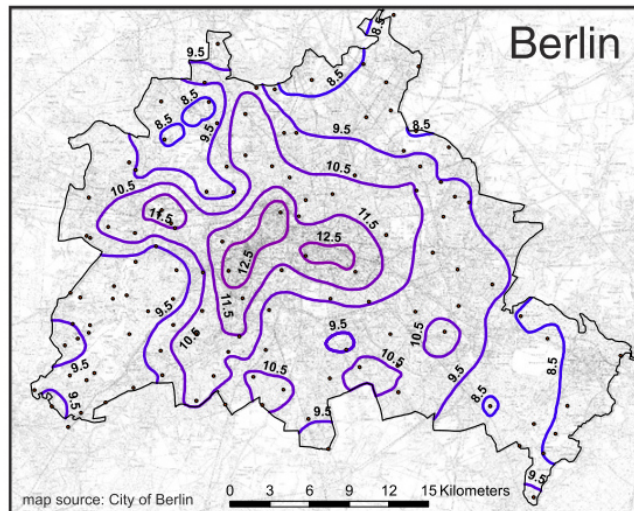
# Increasing groundwater temperatures

Comparison GWT and SAT in Karlsruhe



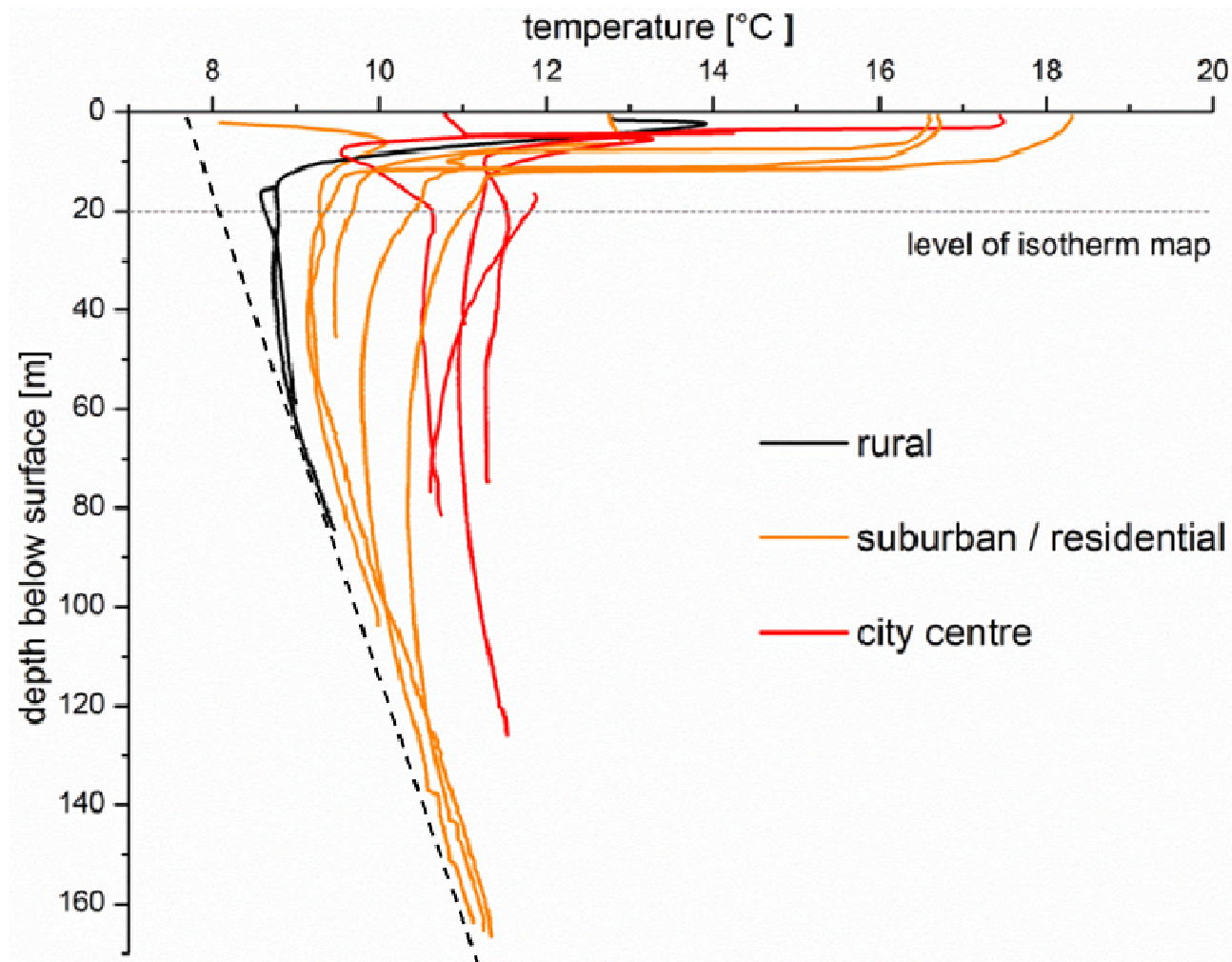
# Increased groundwater temperatures in cities

## Status quo in German cities



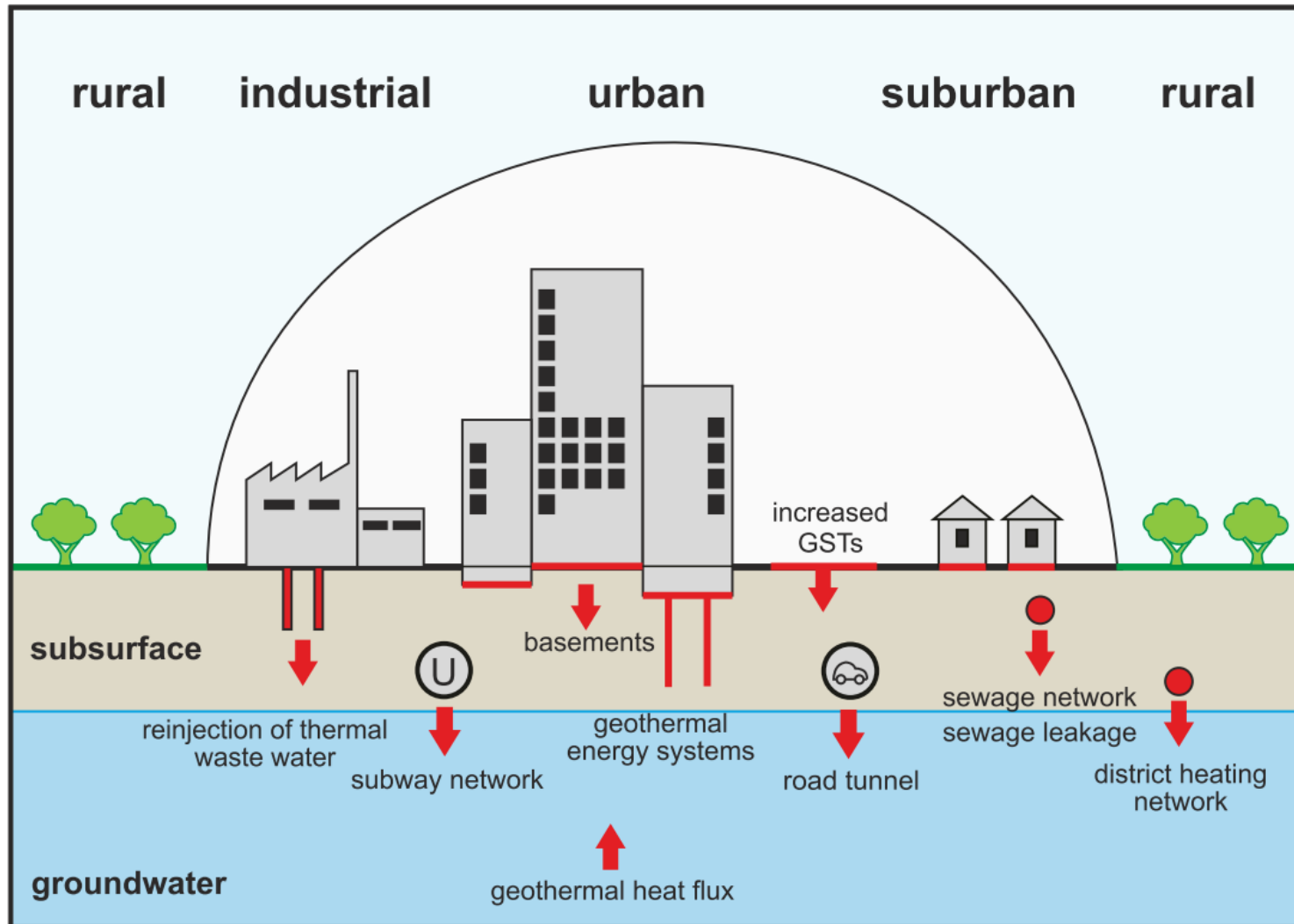
# Subsurface urban heat island (SUHI)

## Temperature-depth-profile in Berlin



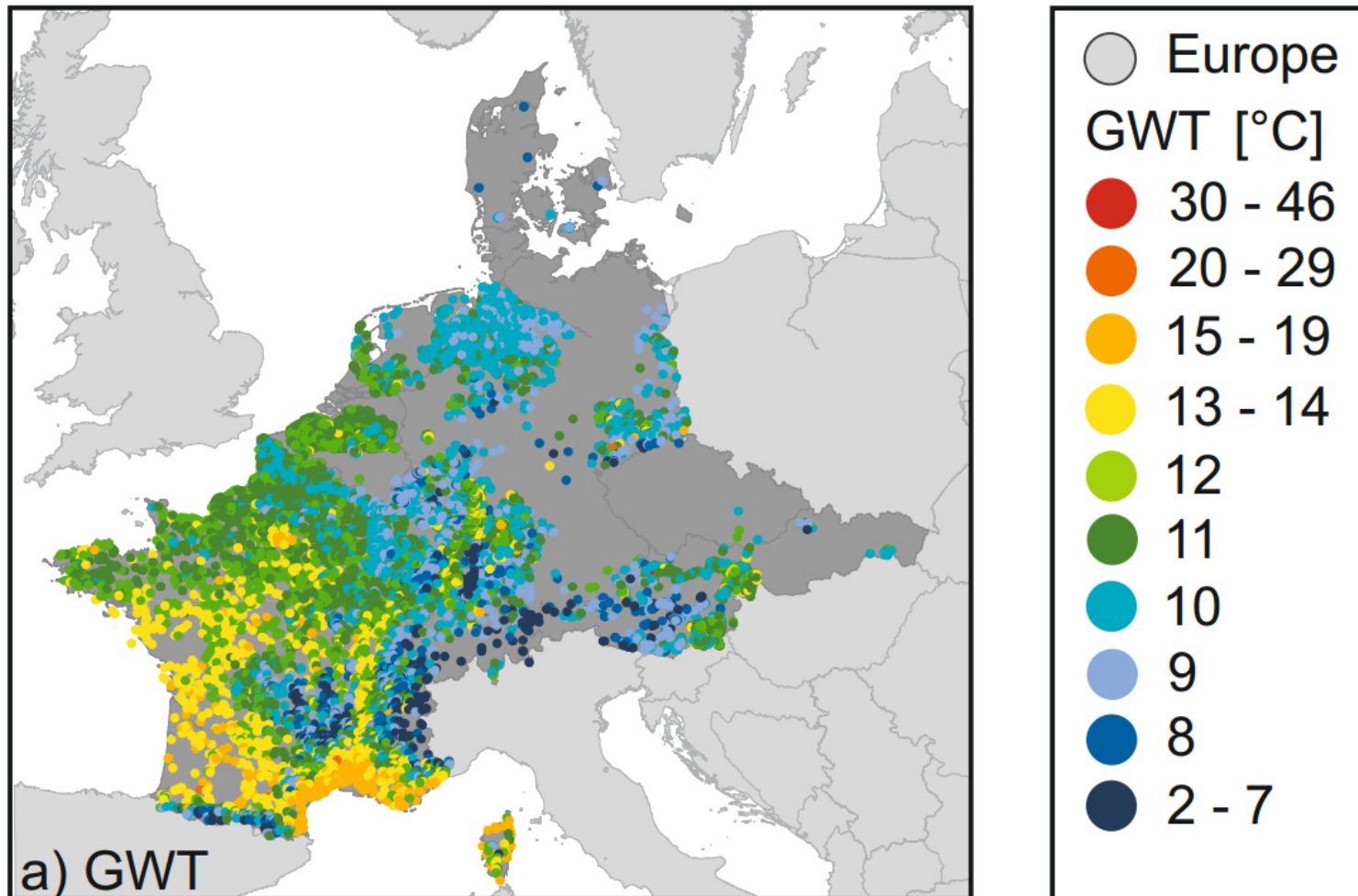
# Numerous anthropogenic sources

SUHI



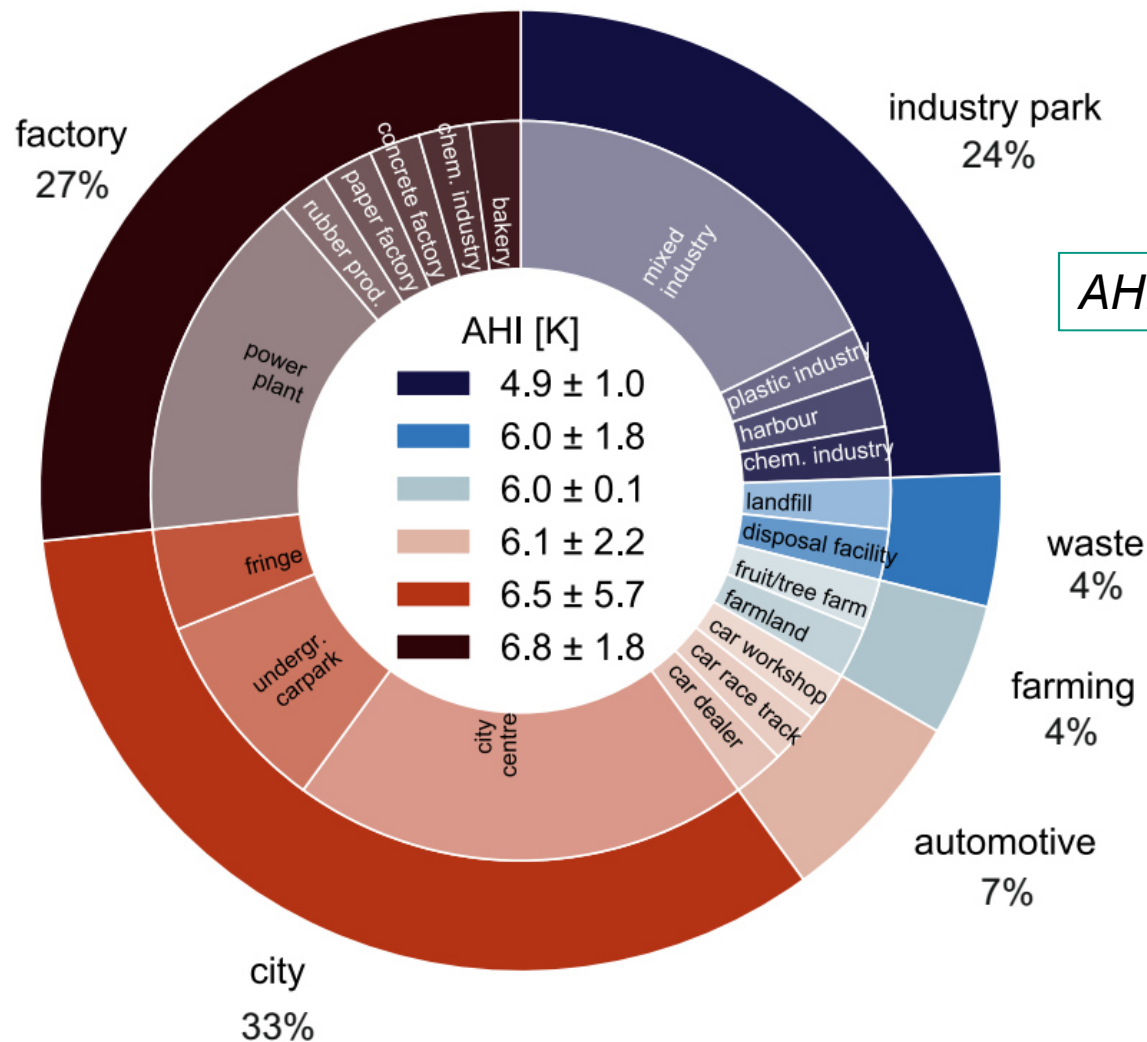
# GWT dominated by regional climate patterns

GWT from 12,000 wells



# Largest heat impact by factory and city

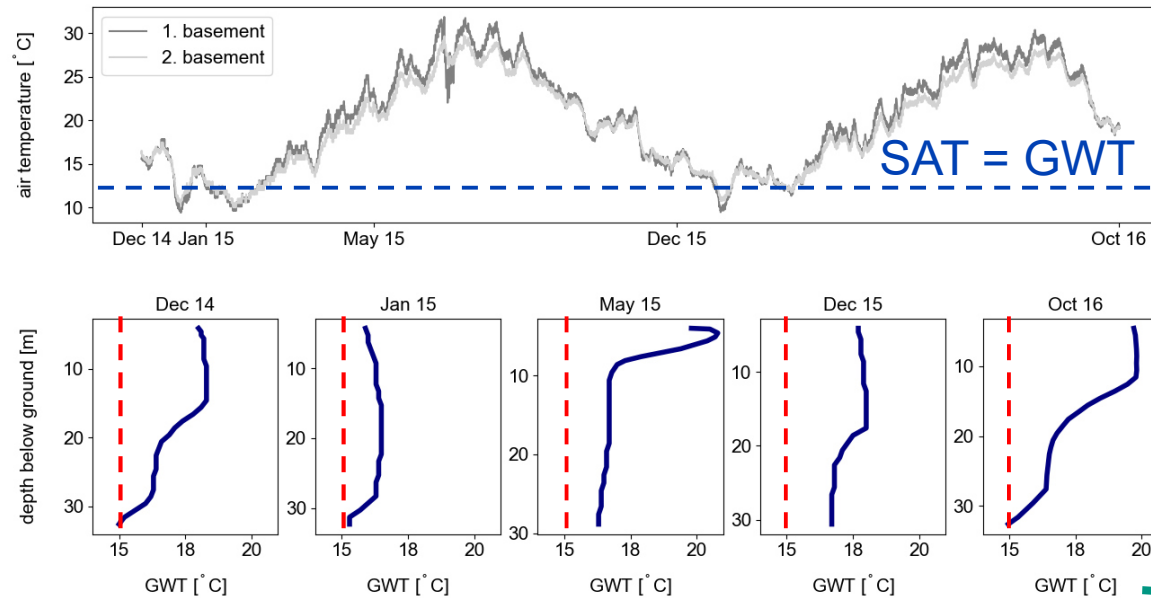
Anthropogenic heat intensity (AHI) by land utilisation class



$$AHI = GWT - \text{median}(GWT_r)$$

# Underground carpark are key heat polluters!

Air temperature and GWT in an underground carpark in Zurich



- ▶ Underground carpark exceeds legally binding threshold value in Switzerland.
- ▶ Underground carpark is “illegal”!

# Three main groundwater fauna groups

## Groundwater fauna

Crustacean



Spengler (2017)

treadworm (*Nematod*)



Fuchs et al. (2006)

flatworm (*Turbellaria*)



Vila Farre et al. (2011)

“earthworm” (*Oligochaetes*)



Halse et al. (2014)

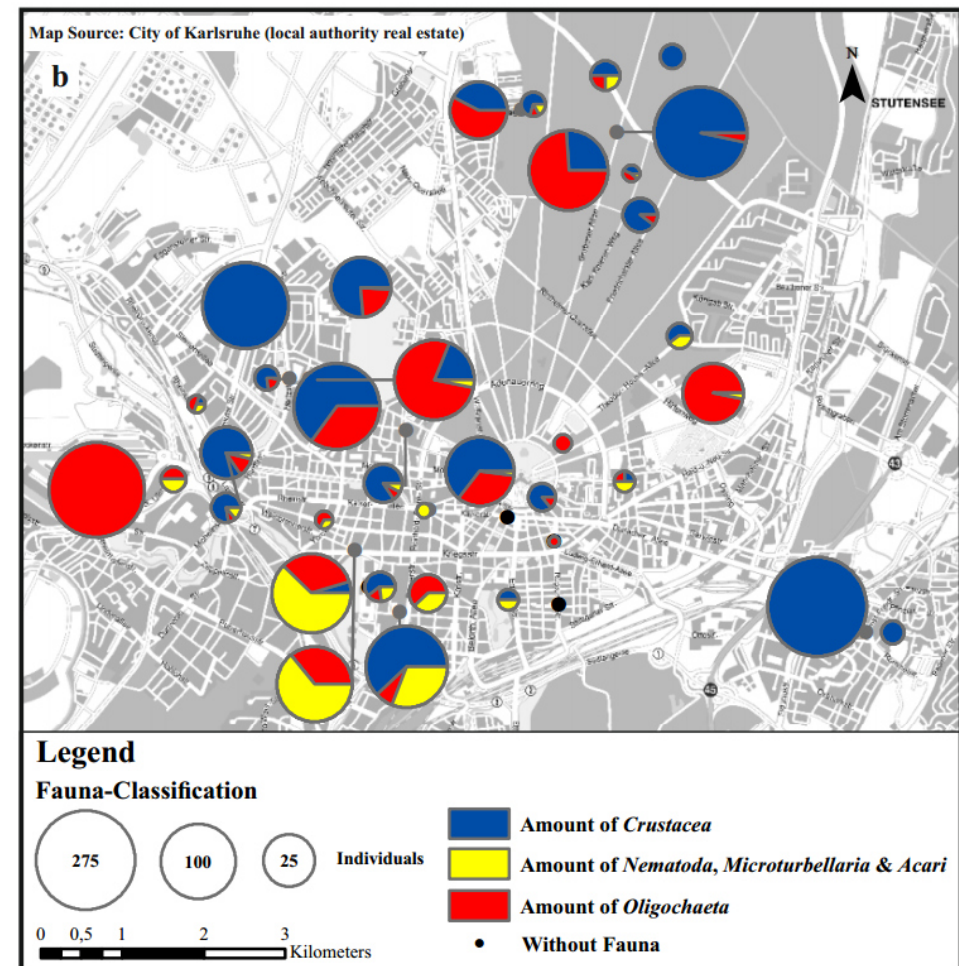
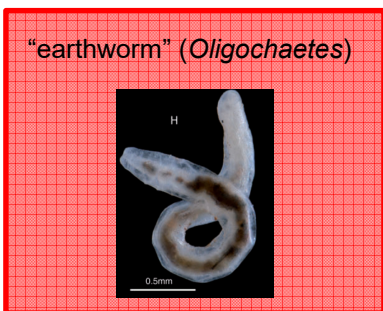
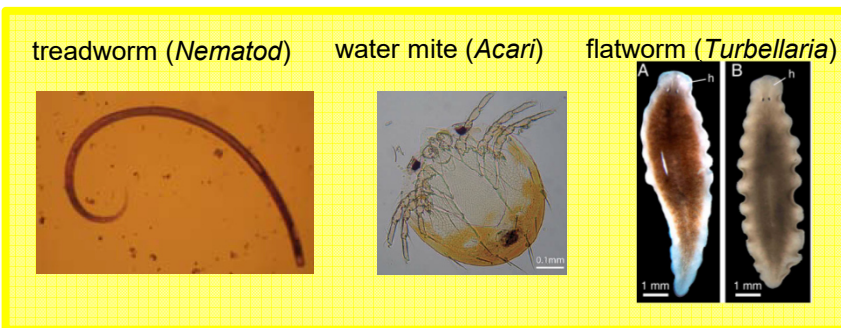
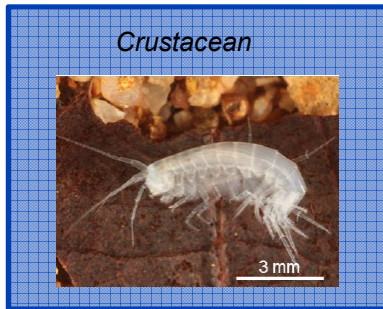
water mite (*Acari*)



de Silva et al. (2015)

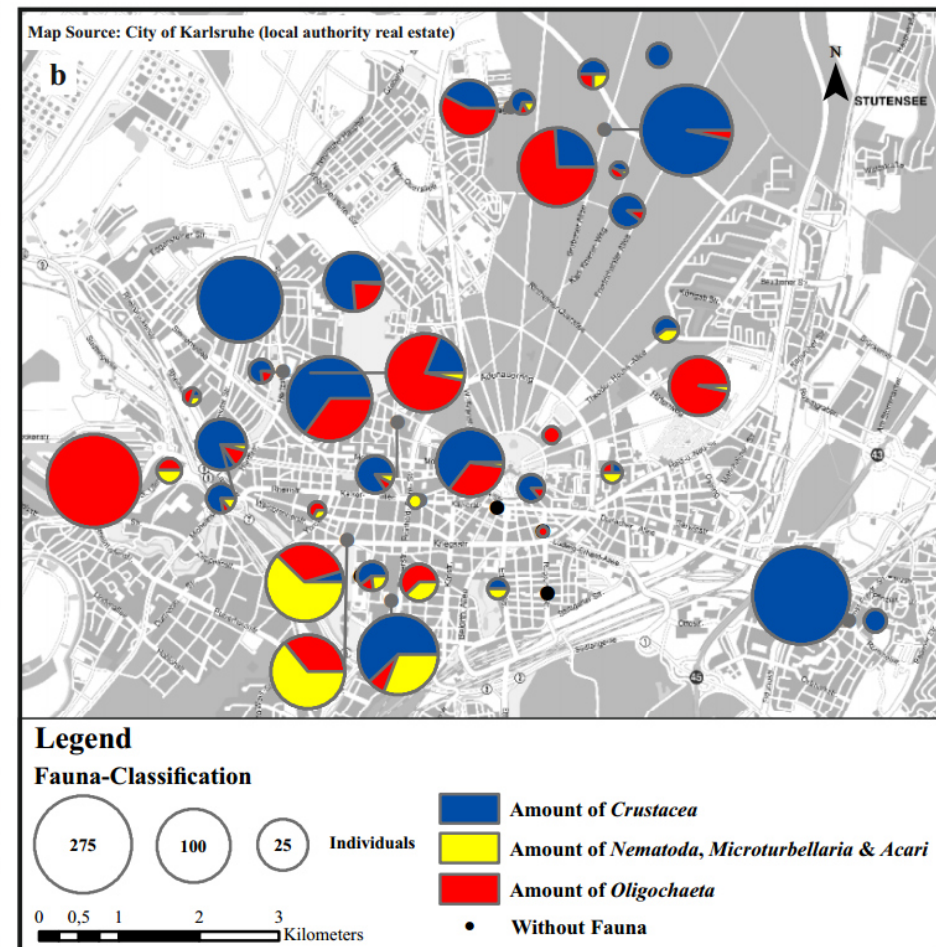
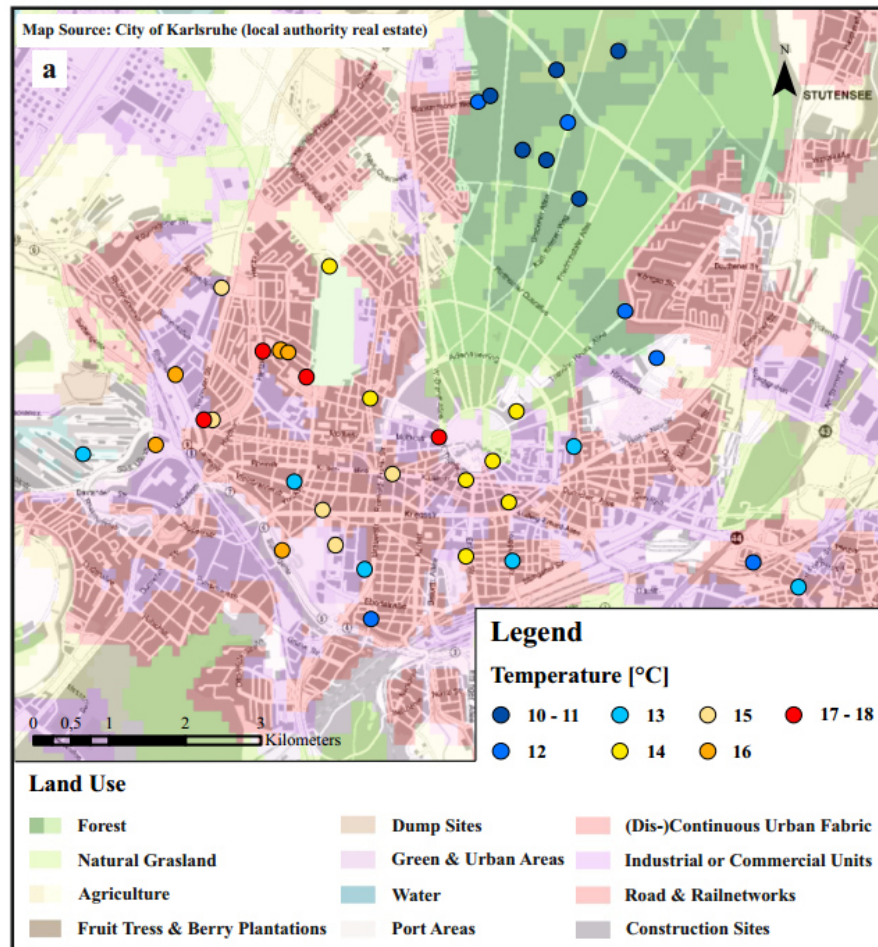
# Heterogeneous distribution of groundwater fauna

## Groundwater fauna



# Fauna influenced by land use and GWT

## Groundwater fauna



Thus, we would like to propose this...



# Increased GWT are an energy source!

## Geothermal potential of worldwide cities

City	Area <sup>a</sup> (km <sup>2</sup> )	Population density <sup>a</sup> (km <sup>-2</sup> )	Aquifer material	Thickness (m)	Porosity <sup>b</sup>	Potential minimal heat content (kJ year <sup>-1</sup> km <sup>-2</sup> )	Heating demand (kJ year <sup>-1</sup> km <sup>-2</sup> )	Capacity for space heating *
Cologne	405	2528	Gravel, sand	10–30	0.15–0.25	$4.8 \times 10^{10}$ – $4.8 \times 10^{11}$	$1.9 \times 10^{10}$	2.5–25.5
Winnipeg	5302	1429	Carbonate	5–15	0.05–0.1	$2.2 \times 10^{10}$ – $2.1 \times 10^{11}$	$4.1 \times 10^{10}$	0.5–5.6
Shanghai	6200	2646	Sand, clay <sup>c</sup>	10–20 <sup>c</sup>	0.2–0.3	$5.0 \times 10^{10}$ – $3.5 \times 10^{11}$	$2.3 \times 10^9$ <sup>d</sup>	22.2–155.1
Tokyo	2187	5874	Sand, clay <sup>e</sup>	30–70 <sup>e,f</sup>	0.2–0.3	$5.0 \times 10^{10}$ – $7.0 \times 10^{11}$	$2.5 \times 10^{10}$ <sup>g</sup>	5.9–48.3
London	1707	4761	Chalk <sup>h</sup>	30–40 <sup>h</sup>	0.05–0.2	$1.1 \times 10^{11}$ – $5.6 \times 10^{11}$	$9.5 \times 10^{10}$ <sup>i</sup>	1.4–6.9
Istanbul	1830	6211	Limestone <sup>j</sup>	10–30	0.05–0.25	$4.4 \times 10^{10}$ – $5.0 \times 10^{11}$	$5.5 \times 10^9$ <sup>k</sup>	8.0–92.9
Prague	496	2504	Sandstone <sup>l</sup>	10–30	0.1–0.3	$4.6 \times 10^{10}$ – $5.3 \times 10^{11}$	$9.6 \times 10^9$ <sup>m</sup>	4.8–55.0

\* groundwater temperature **reduction** by 2 - 6 K

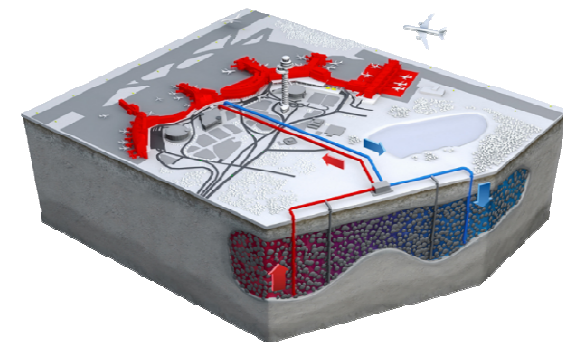
- Increased GWT could be used by geothermal applications (ATES, GWHP, GSHP), thus restore the natural thermal state of the aquifer (SUHI).

# Is Heat a Contaminant?

- ▶ Legally yes (EU WFD)
  - Heat is a potential pollutant.
- ▶ Increased GWT may have negative effects on:
  - chemical and physical conditions of groundwater,
  - groundwater fauna,
  - and drinking water quality.



- ▶ However, increased GWTs are also a huge energy source, which can be harnessed by geothermal systems.



Aquifer Thermal Energy Storage (ATES)  
system for heating (Arlanda airport in Stockholm)

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