8th WPGI 2024

geosolving

TECHNISCHE UNIVERSITÄT DARMSTADT

FEASIBILITY AND POTENTIAL STUDY FOR THE USE OF GEOTHERMAL ENERGY IN TWO GERMAN RAILWAY TUNNELS

H. Zachert, R. Zeus – Technical University Darmstadt – Institute of Geotechnics

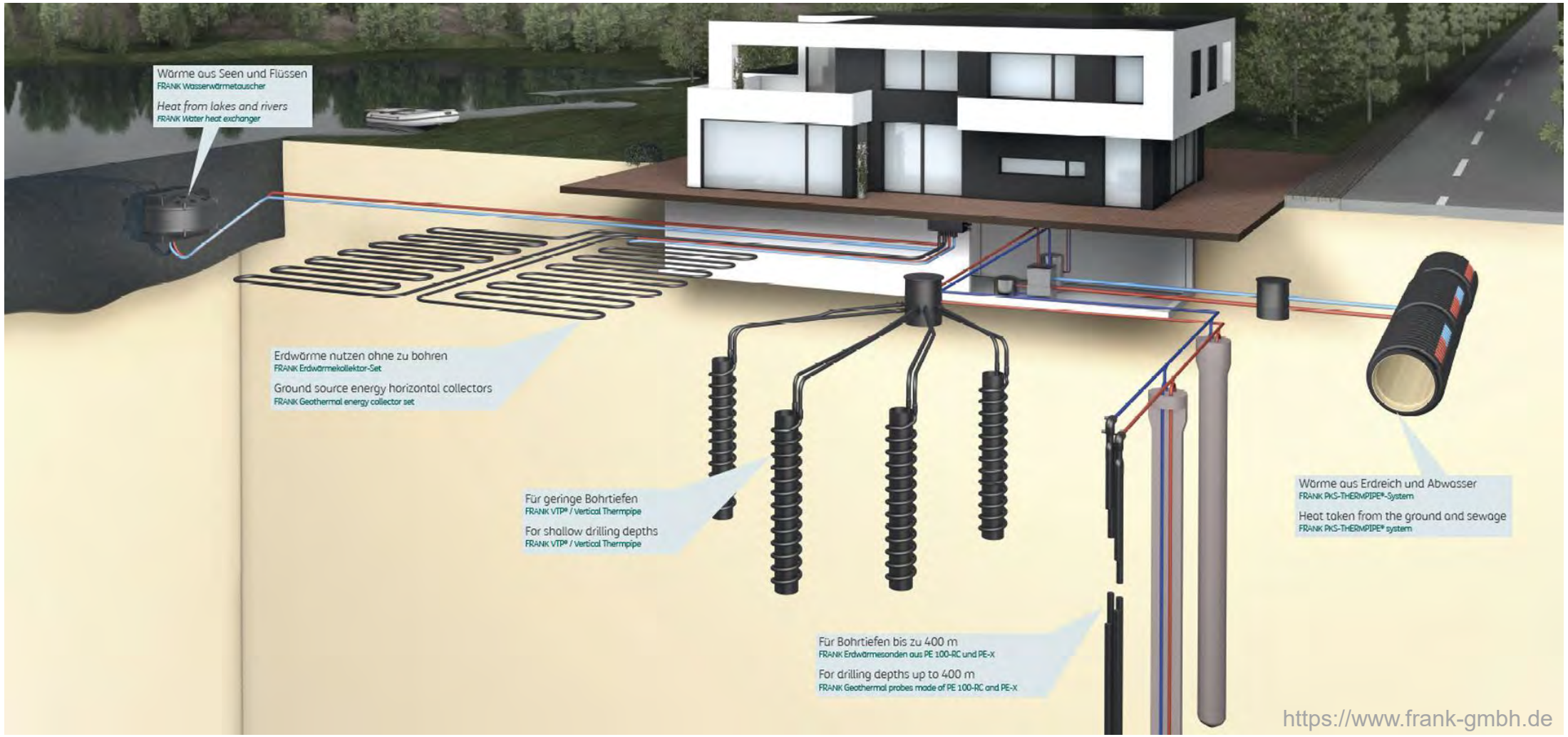
M. Scerbo, S. De Feudis, A. Insana, M. Barla – geosolving, Torino

elgip

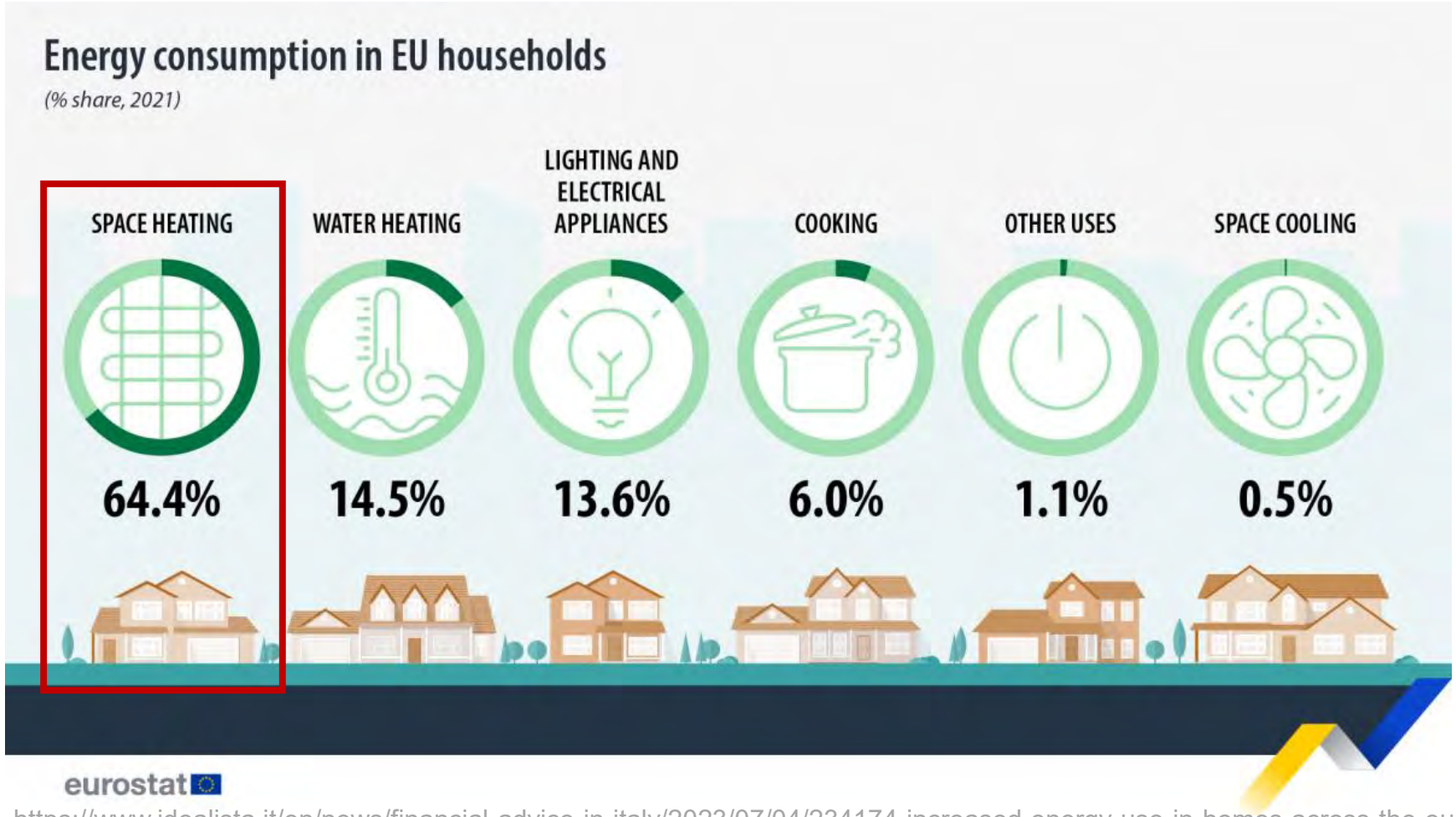
Polish Geological Institute
National Research Institute

ELGIP Workshop
Urban Geology & Geotechnics
@ 8. WPGI - 16.10.2024 in Łódź

GEOTHERMAL ENERGY



WHY GEOTHERMAL ENERGY?



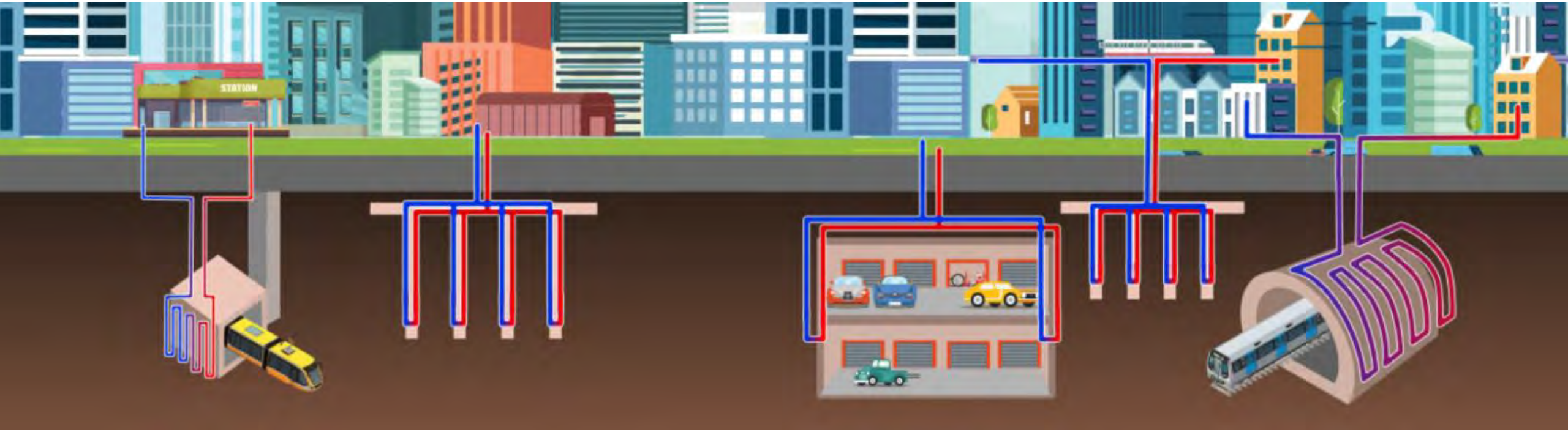
https://www.idealista.it/en/news/financial-advice-in-italy/2023/07/04/234174-increased-energy-use-in-homes-across-the-eu

About 30% of the total energy consumption in Poland goes to the private housholds.

Thereof, 65% are used for heating.

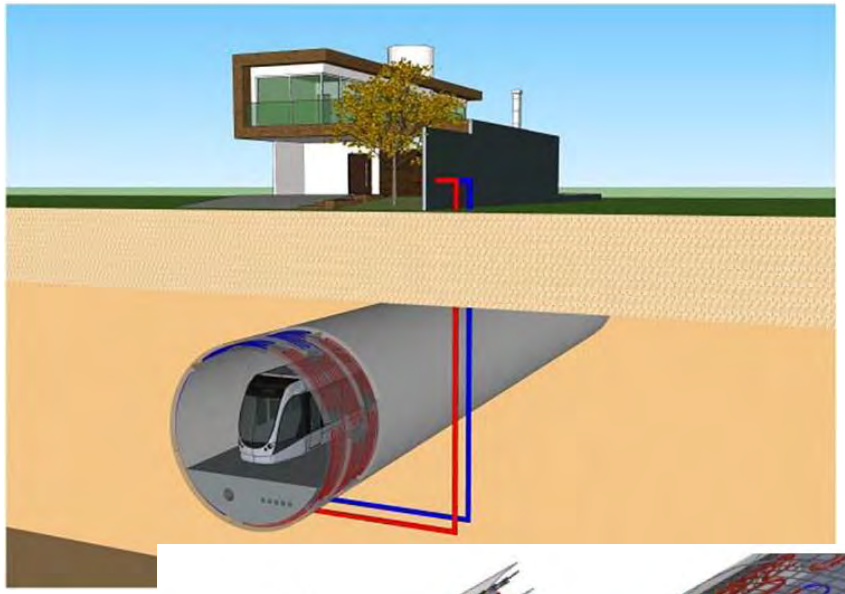
➔ About 20% of the total energy consumption could be covered by geothermal energy

ENERGY GEOSTRUCTURES

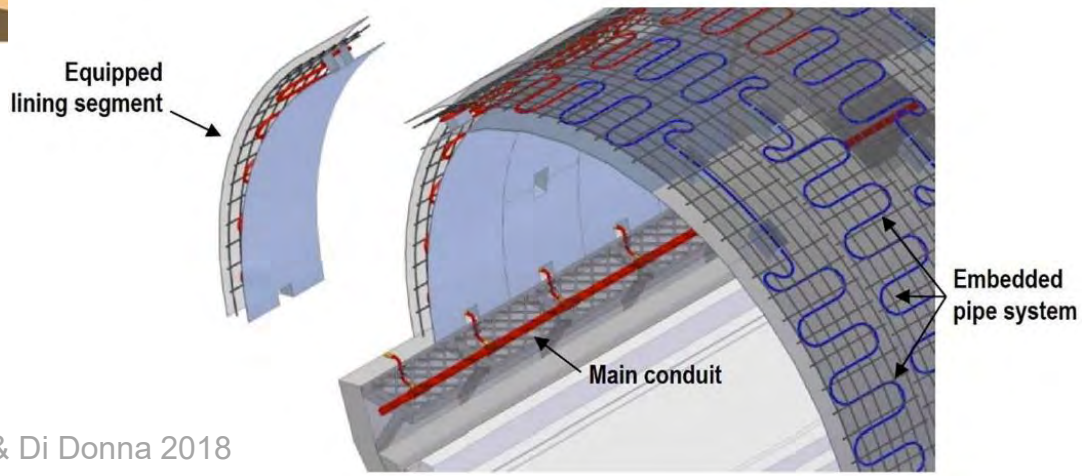


https://www.ca-foliage.eu/

ENERGY TUNNELS



Csesznák et al. 2016



Barla & Di Donna 2018

Barla et al. 2017

Frodl, S. et al. 2010

STUDIES

- Feasibility study for Deutsche Bahn (DB)
- DB aims to be CO_2 neutral by 2040

➢ explore the energy potential

➢ and the technical feasibility

➢ for two projects in different geology

TECHNISCHE UNIVERSITÄT DARMSTADT

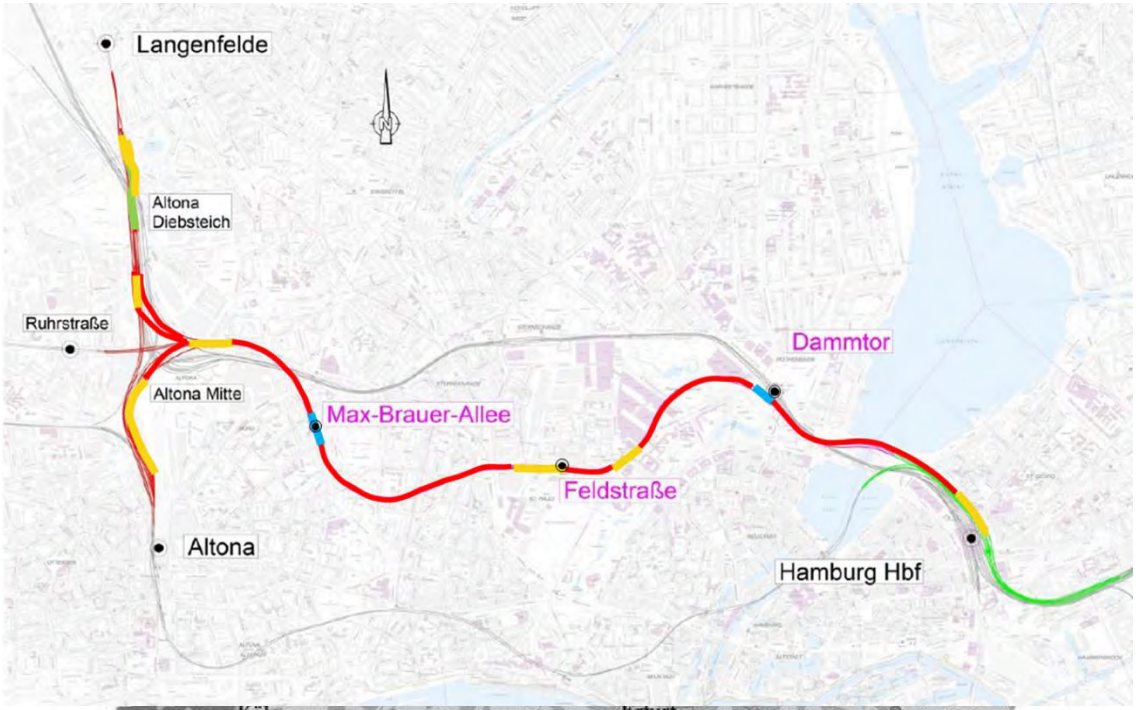
STUDIES

- Feasibility study for Deutsche Bahn (DB)
- DB aims to be CO_2 neutral by 2040

➢ explore the energy potential

➢ and the technical feasibility

➢ for two projects in different geology

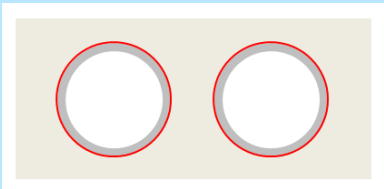


Location: **Hamburg**

Name: Verbindungsbahn-Entlastungstunnel

Lenght: approx. 12.8 km

Type: Twin Tunnel



STUDIES

- Feasibility study for Deutsche Bahn (DB)
- DB aims to be CO_2 neutral by 2040

➢ explore the energy potential

➢ and the technical feasibility

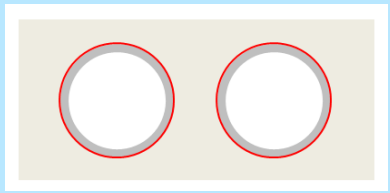
➢ for two projects in different geology

Location: **Stuttgart**

Name: Pfaffensteigtunnel

Lenght: approx. 22.3 km

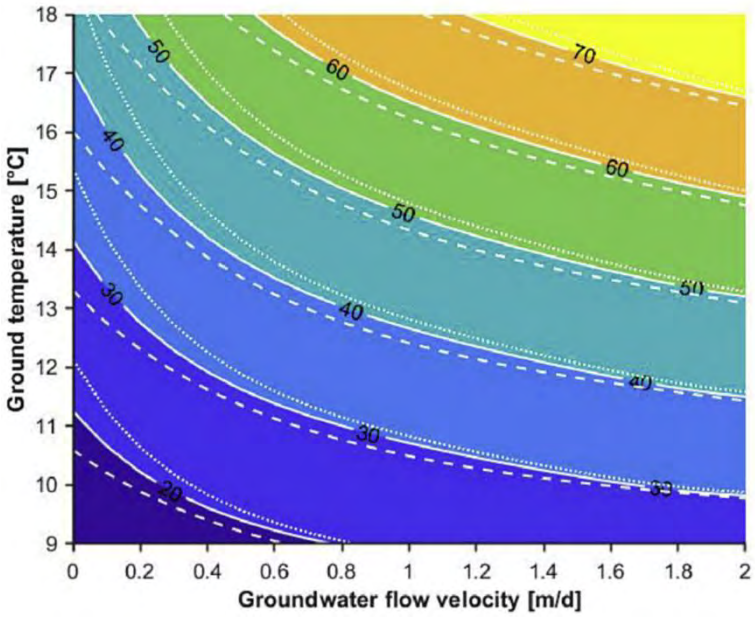
Type: Twin Tunnel



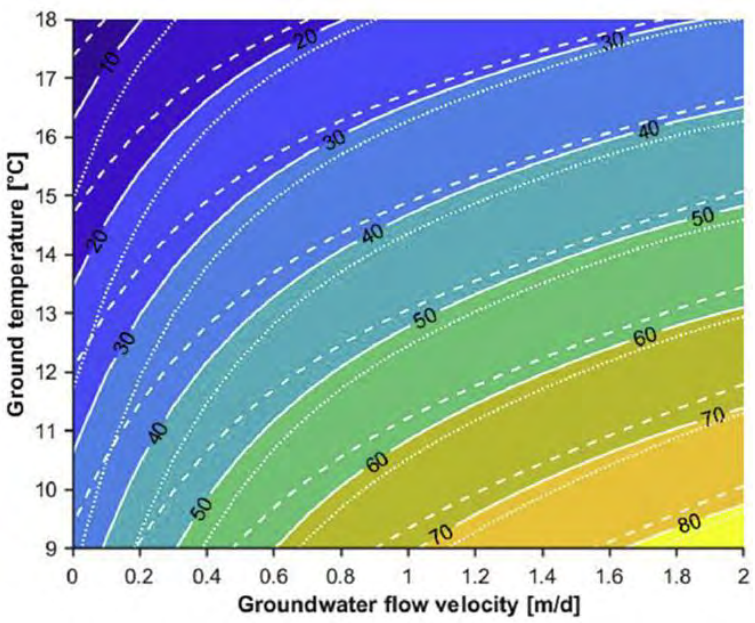
POTENTIAL ANALYSIS

Nomogram-approach by Insana et al. 2020

Winter (heating)
Geothermal potential W/m²



Summer (cooling)
Geothermal potential W/m²



λ=0.9 W/mK λ=2.26 W/mK λ=3.9 W/mK

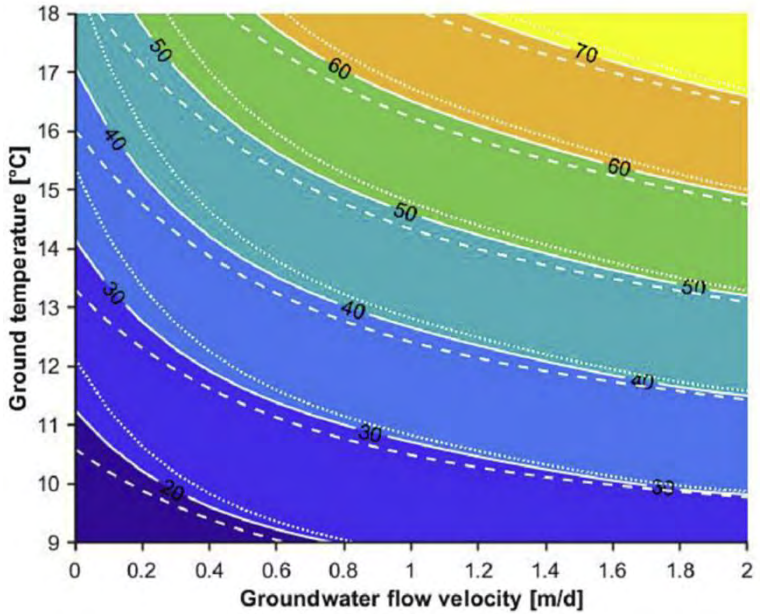
Main assumptions:

- Operation full load 30 days
- Sole-flow 0,9 m/s
- Sole-entry temp. W. 4°C
- Sole-entry temp. S. 28°C

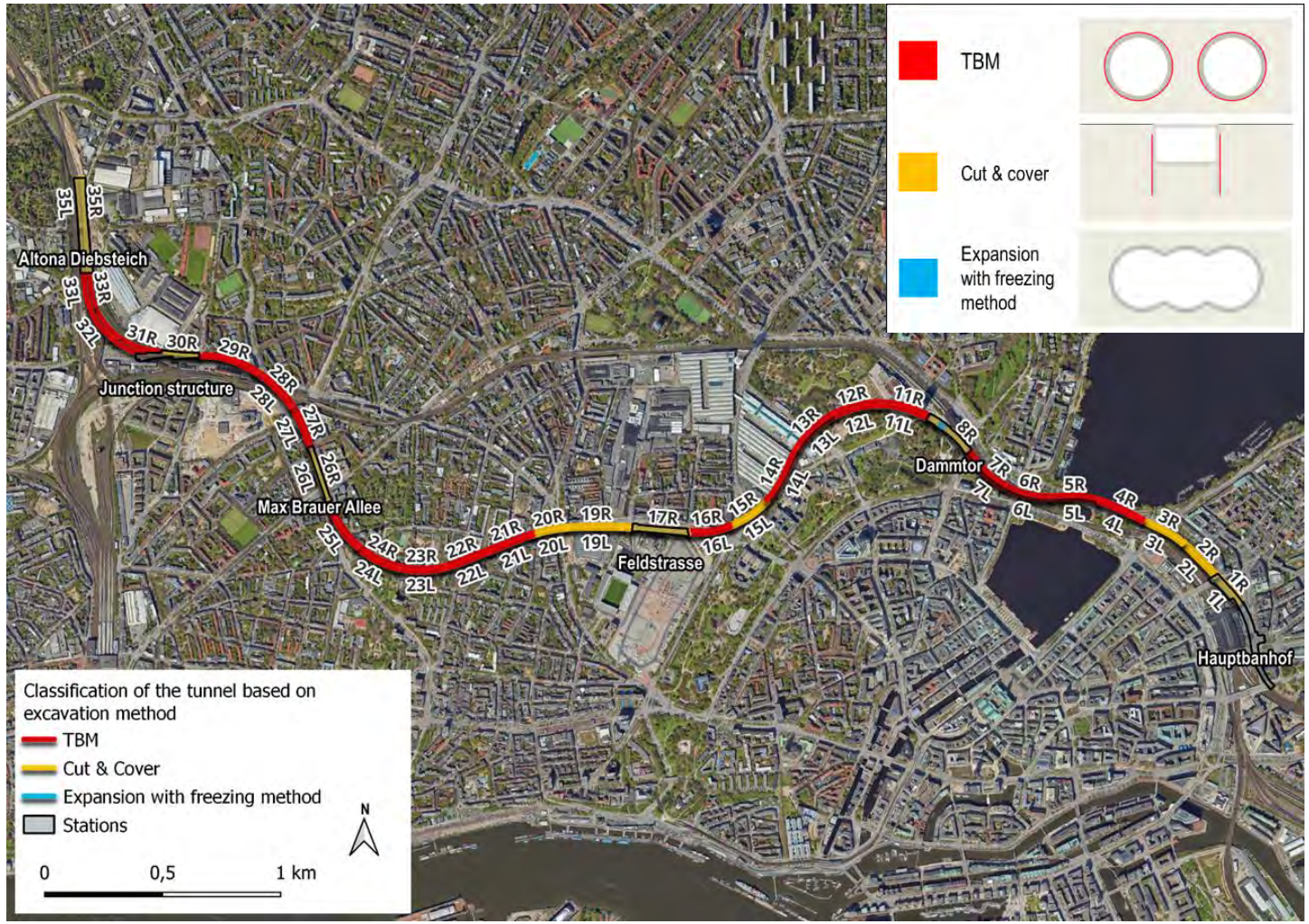
POTENTIAL ANALYSIS

Procedure

- Define tunnel sections with <u>constant</u>
  - Geology
  - Cross section
  - Groundwater flow
- Extract heating/cooling energy potential W/m²
- Here: update based on FE simulations due to twin tunnel

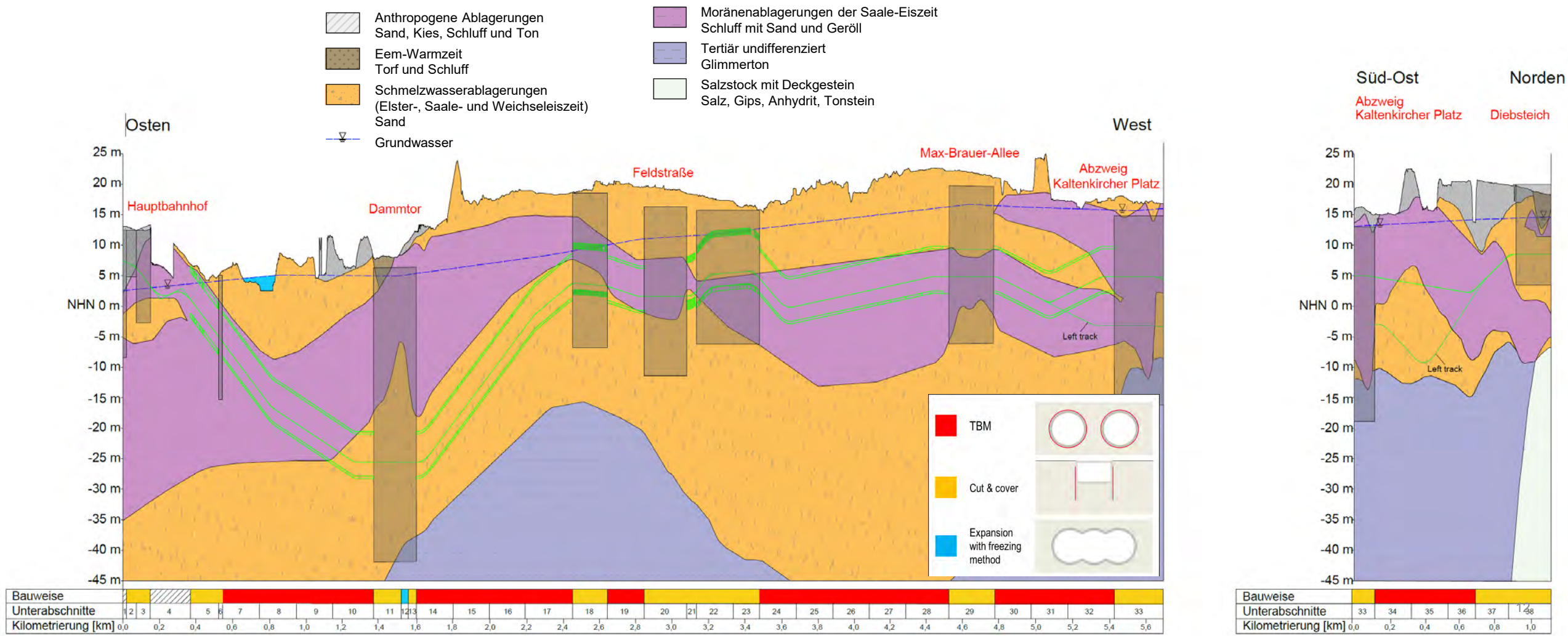


HAMBURG – CROSS SECTIONS

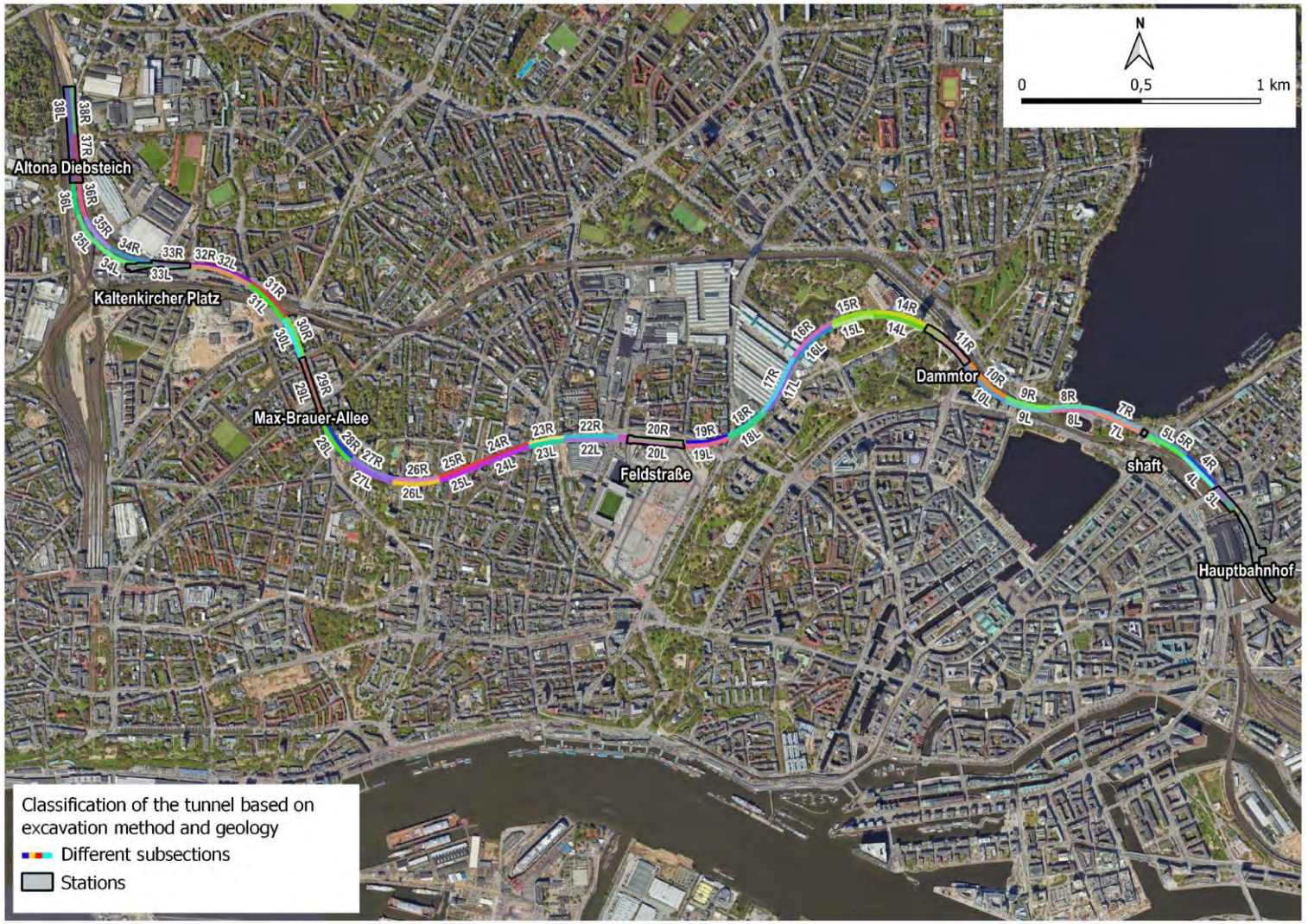


- Mainly Tunnel boring machine
- Stations in cut & cover
- Total tunnel length 12.8 km
- Preliminary tunnel route, not yet fixed!

HAMBURG – GEOLOGY

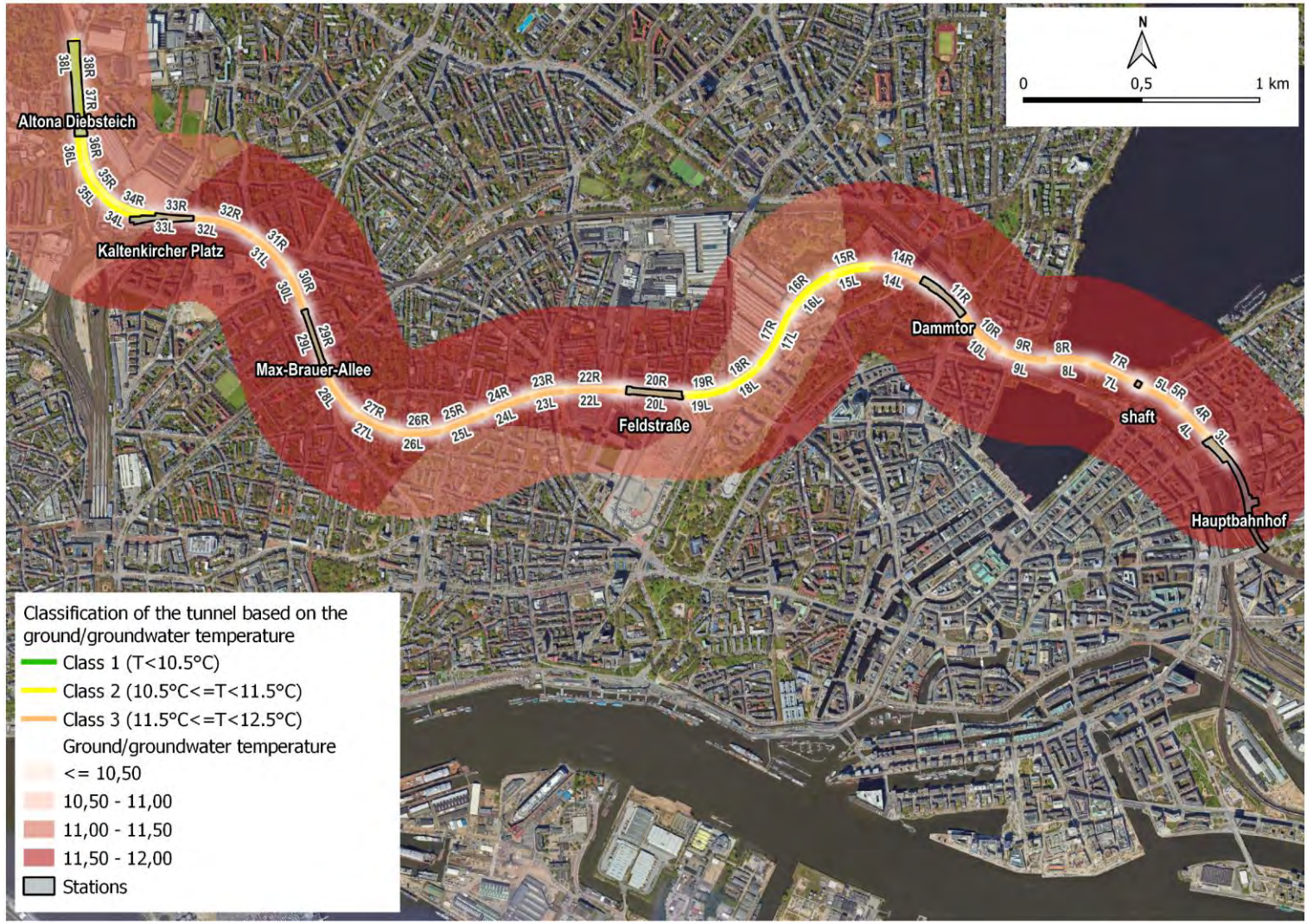


HAMBURG – SUBSECTIONS



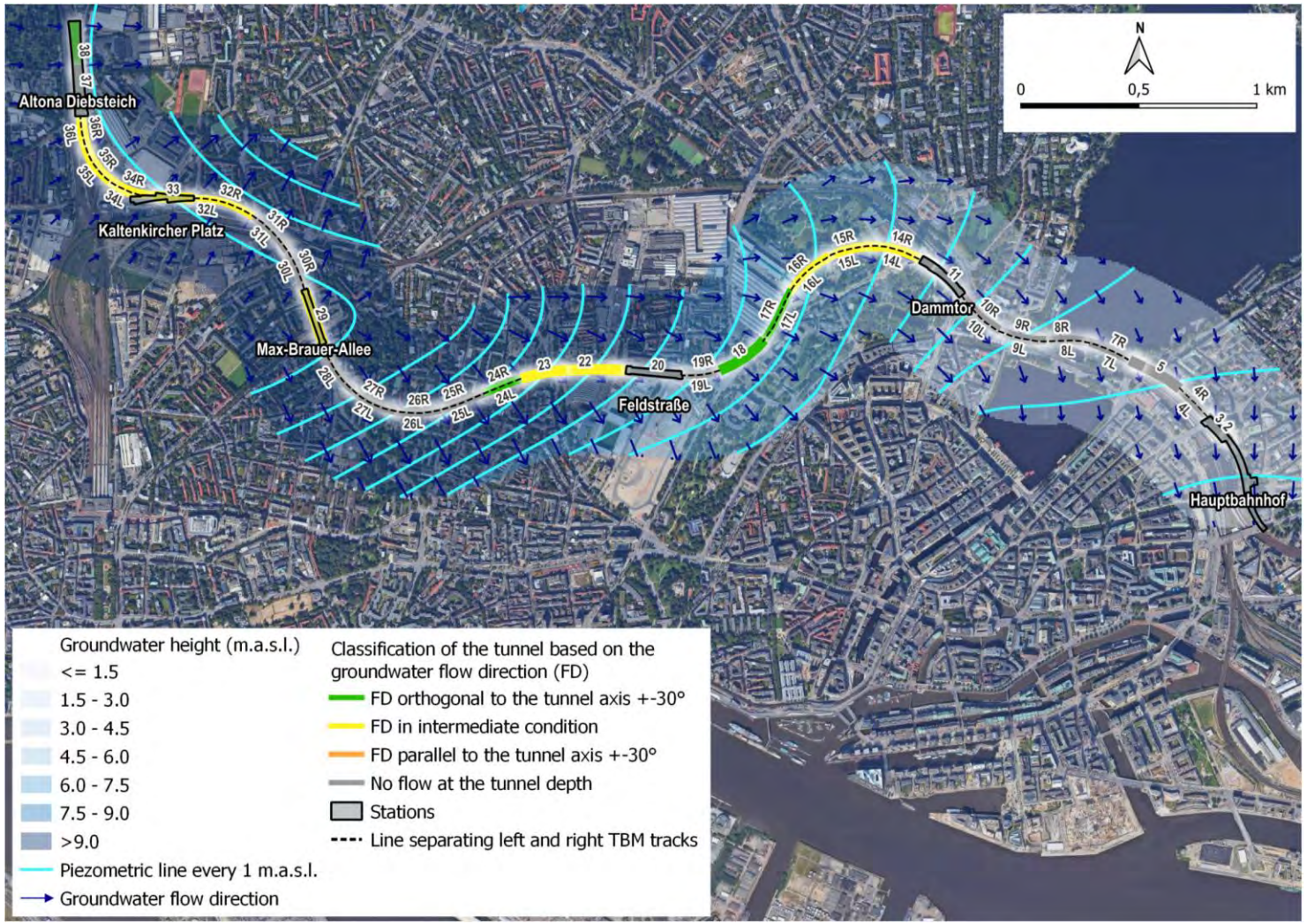
- Subsections with equal
  - Geology
  - Construction method
  - Hydrological conditions

HAMBURG – TEMPERATURE



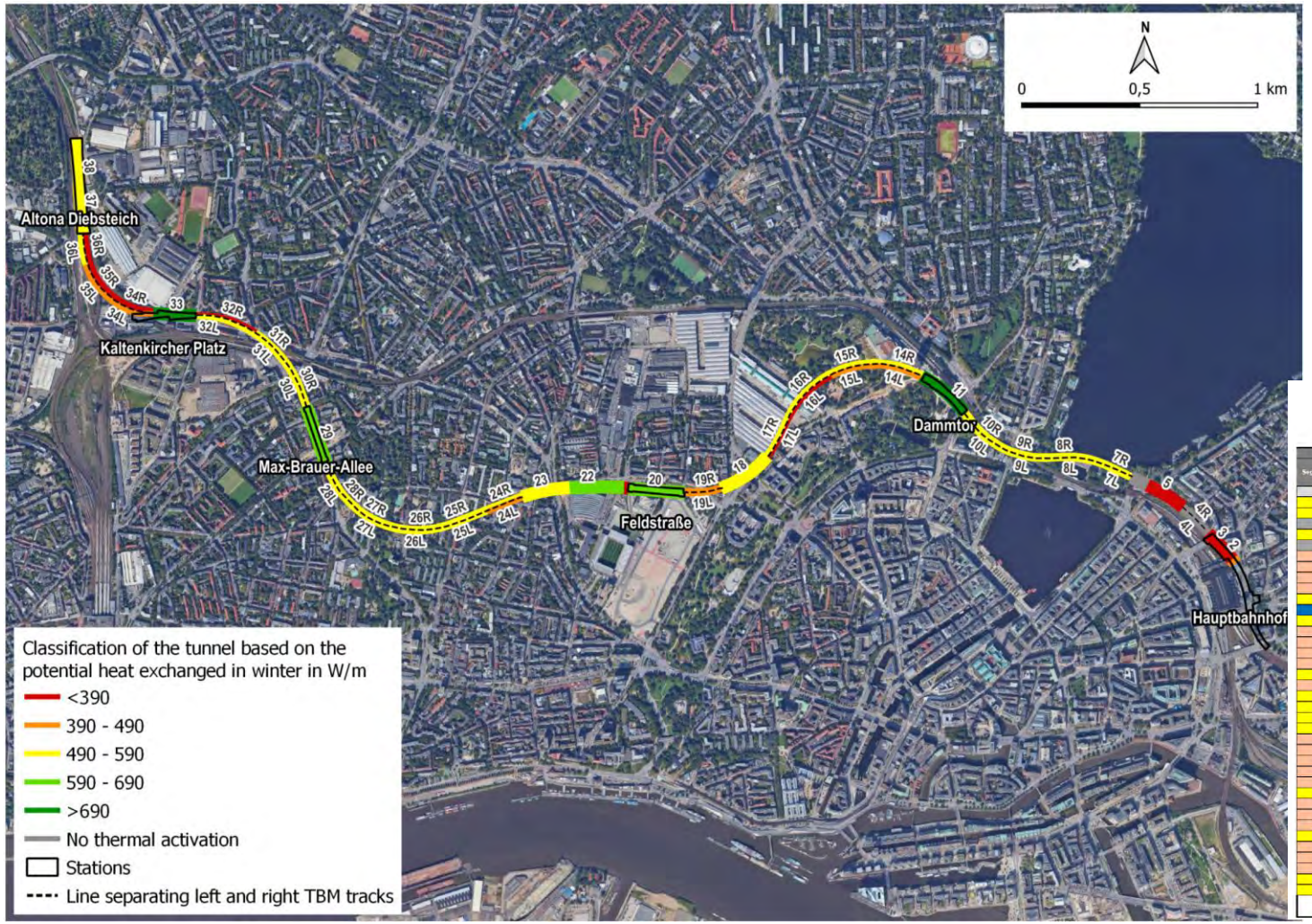
- Temperatures extracted from public data
- Assigned to the segments

HAMBURG – GROUNDWATER

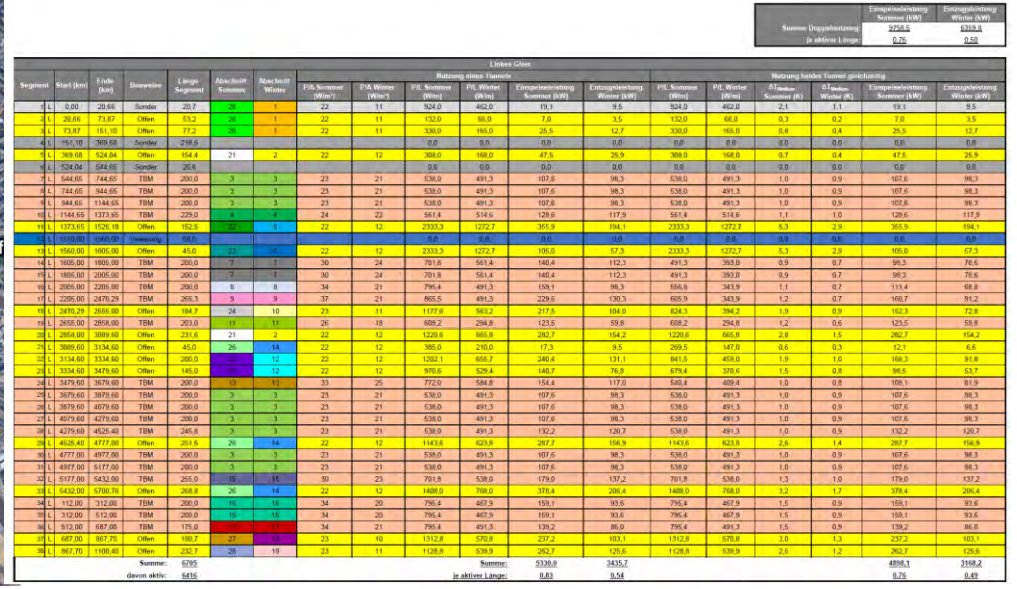


- Groundwater flow
  - Velocity
  - Direction

HAMBURG – POTENTIAL (WINTER)



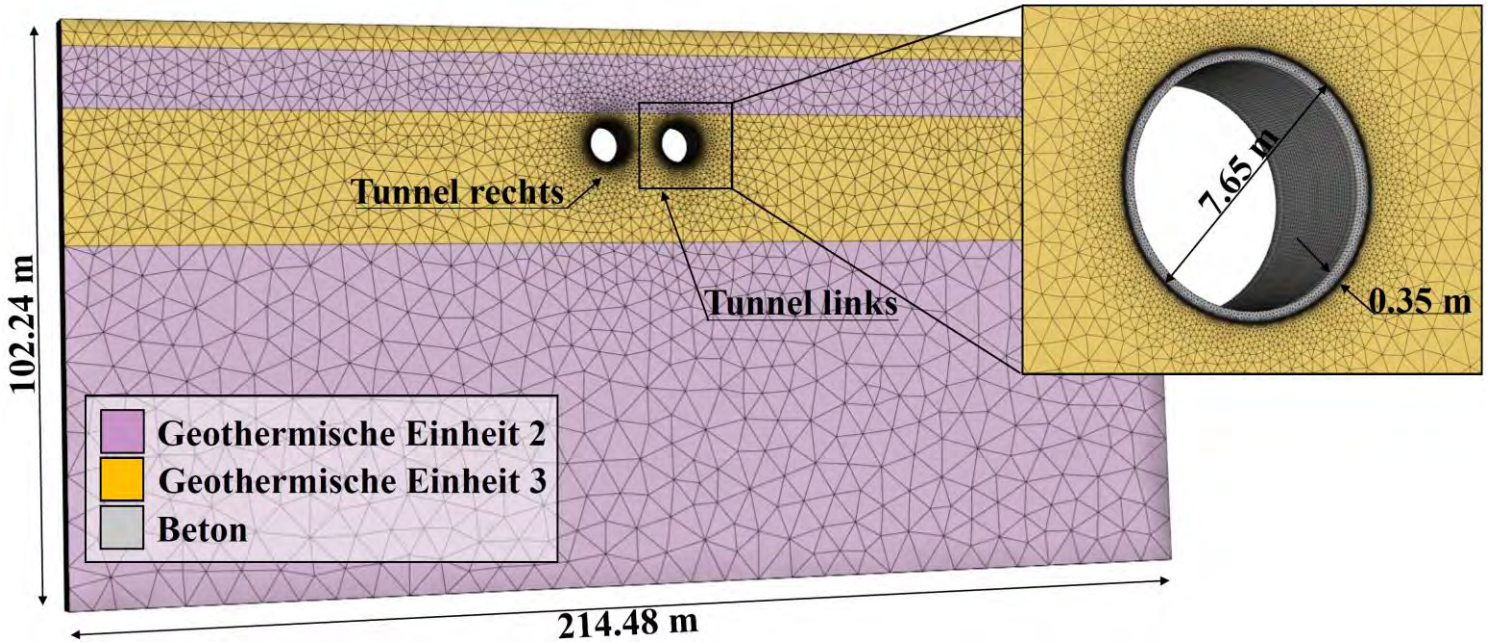
- Energy potential in kW per segment for heating and cooling
- Interaction between two tunnels needs not considered



STUTTGART

Due to confidentiality restrictions, the results, obtained for the Stuttgart tunnel project, can not be shared in this document.

NUMERICAL SIMULATIONS



Goals:

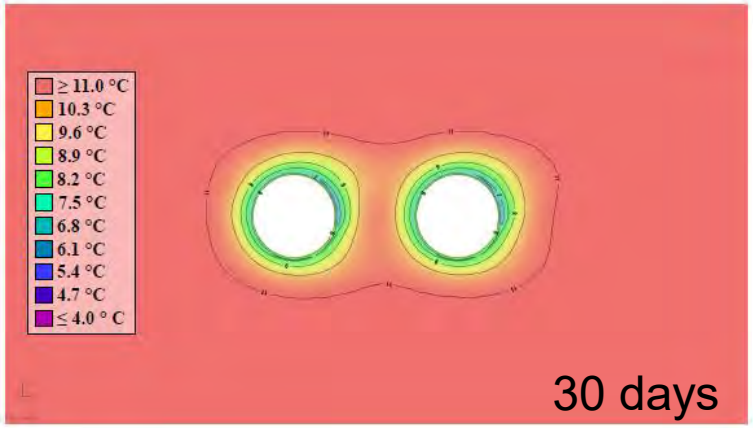
- Improve accuracy compared to the nomograms
- Validate assumptions
- Check for interaction of the two tunnels

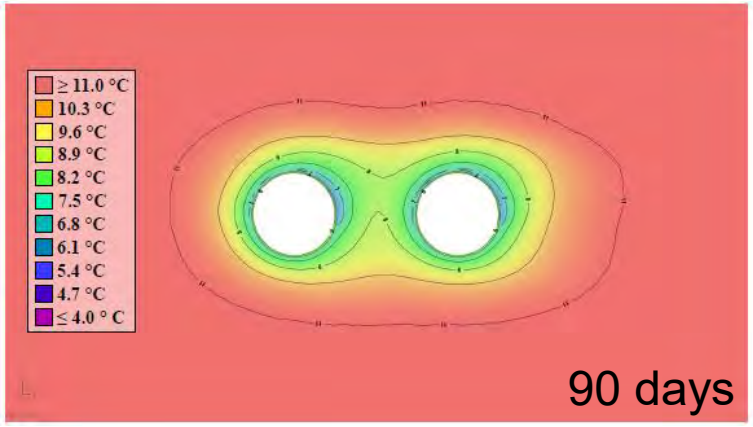
NUMERICAL SIMULATIONS

Findings:

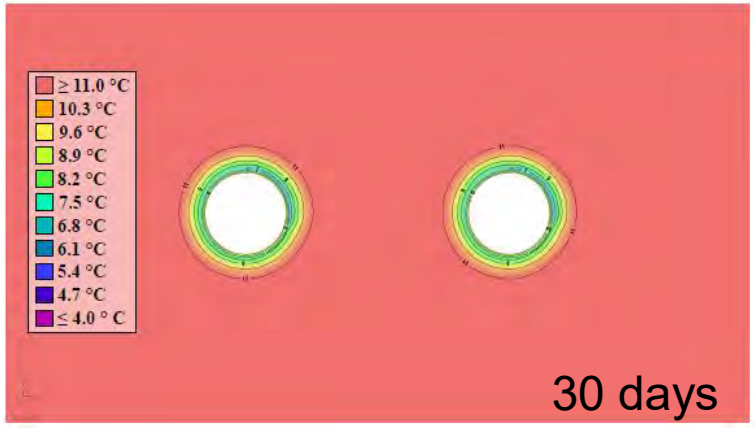
- Interaction in Hamburg
- No interaction in Stuttgart

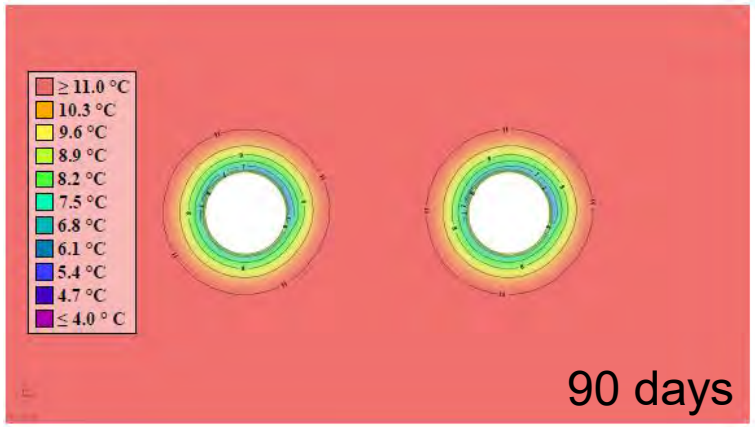
Hamburg - Winter





Stuttgart - Winter





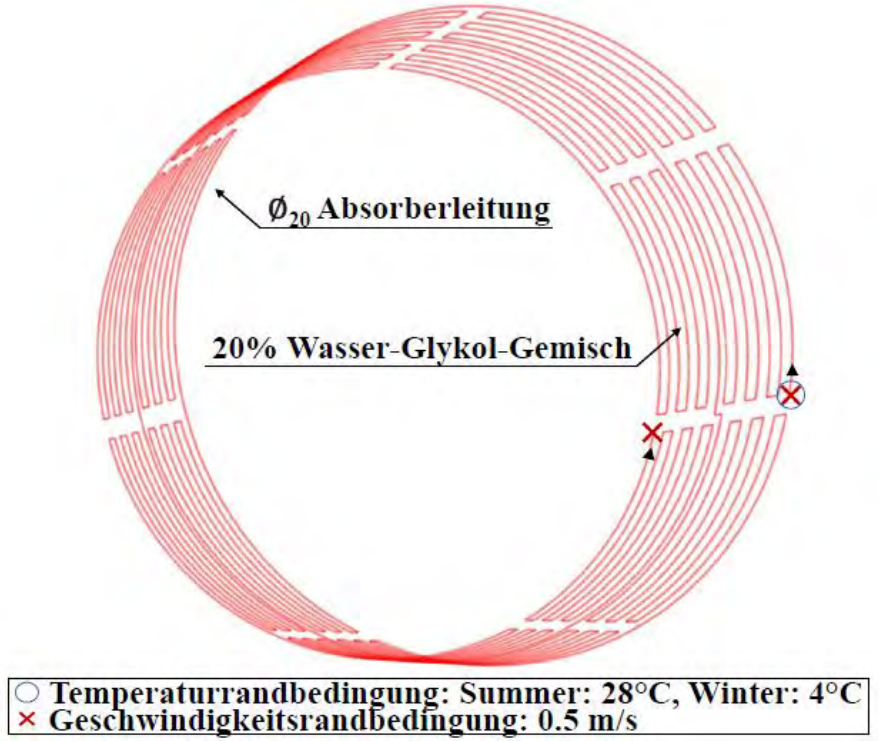
NUMERICAL SIMULATIONS

Findings:

- Interaction in Hamburg
- No interaction in Stuttgart

- Need to couple two segments to increase the spreading of incoming and outgoing temperature

➔ Correction factors for the final energy potential



FINAL ENERGY POTENTIAL

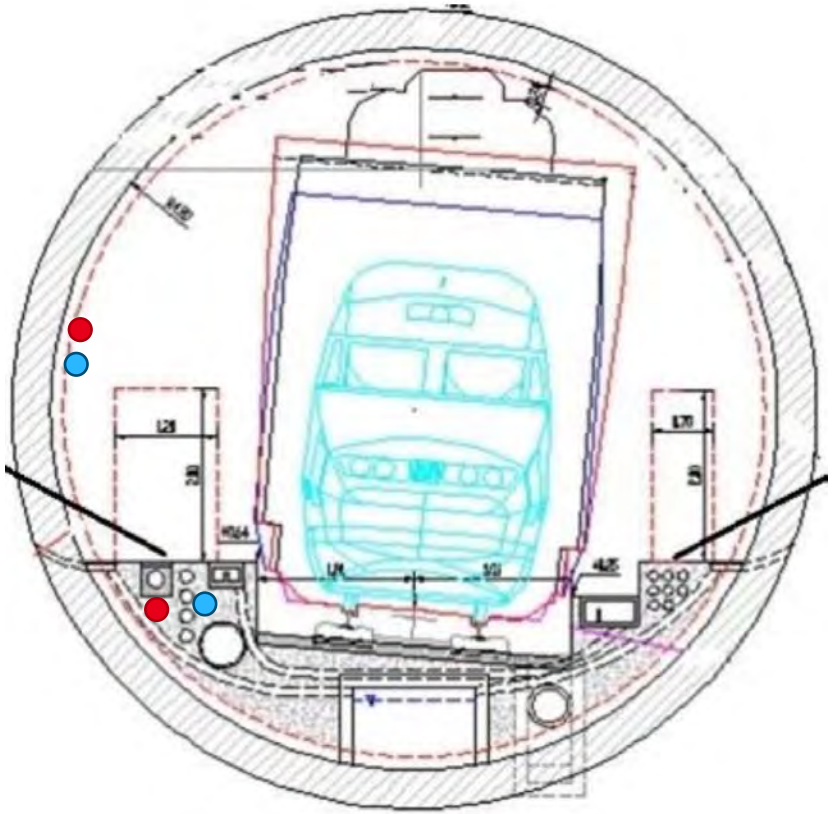
	Hamburg		Stuttgart
Heating (winter)	4.1 MW | 0.39 W/m 3.7 MW | 0.35 W/m		30 days full load 90 days full load
Cooling (summer)	7.8 MW | 0.74 W/m 7.1 MW | 0.67 W/m		30 days 90 days
Housholds equivalent (winter)	2300		

confidential

FEASIBILITY

Things to consider:

- Who operates the system?
- Who owns the energy and who sells it?
- Dimensions of the piping
- Pumps etc.



Poti & Chabert 2020

- Material of the piping
  - In base concrete: PE
  - In free area: stainless steel (expensive)

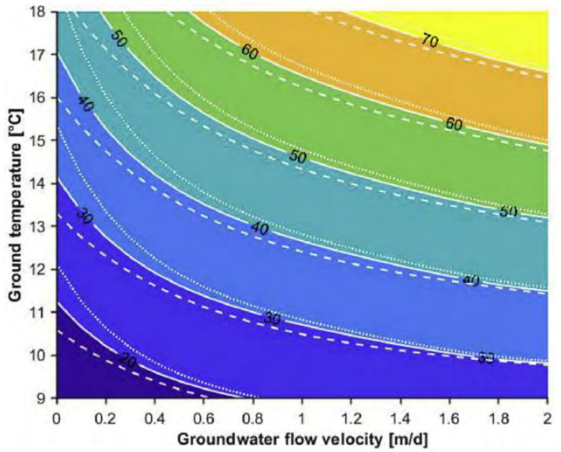
- Costs (without pumps)
  - Approx. 1.6 – 2.7 cent / kWh

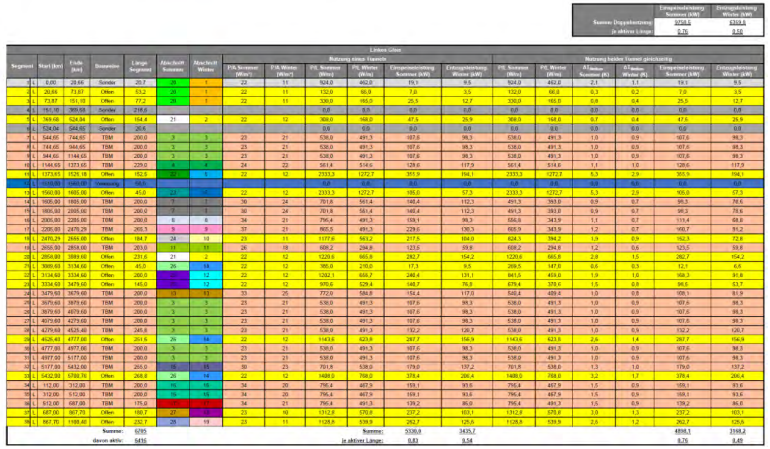
SUMMARY

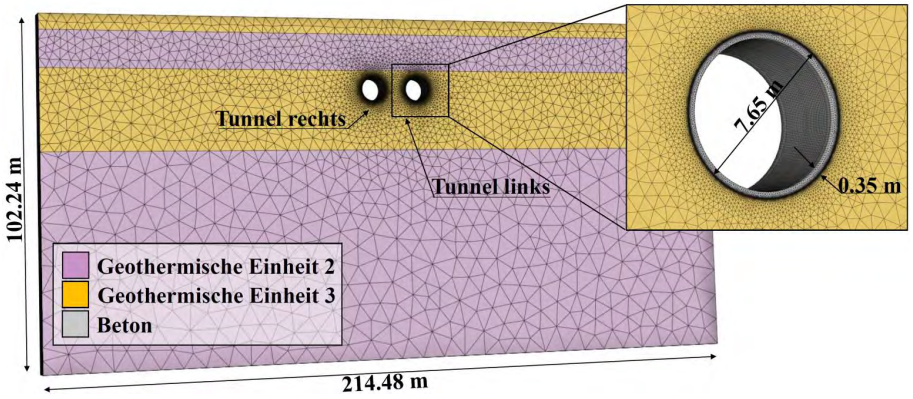
Nomograms by Insana et al. provide a reliable source for an early phase potential analysis

Energy extraction from German Railway tunnels is
- technically feasible
- high potential
- cheap

Spotwise FE simulations help improving accuracy and overcoming natural limitations of the nomograms







THANK YOU FOR YOUR ATTENTION

hauke.zachert@tu-darmstadt.de