



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

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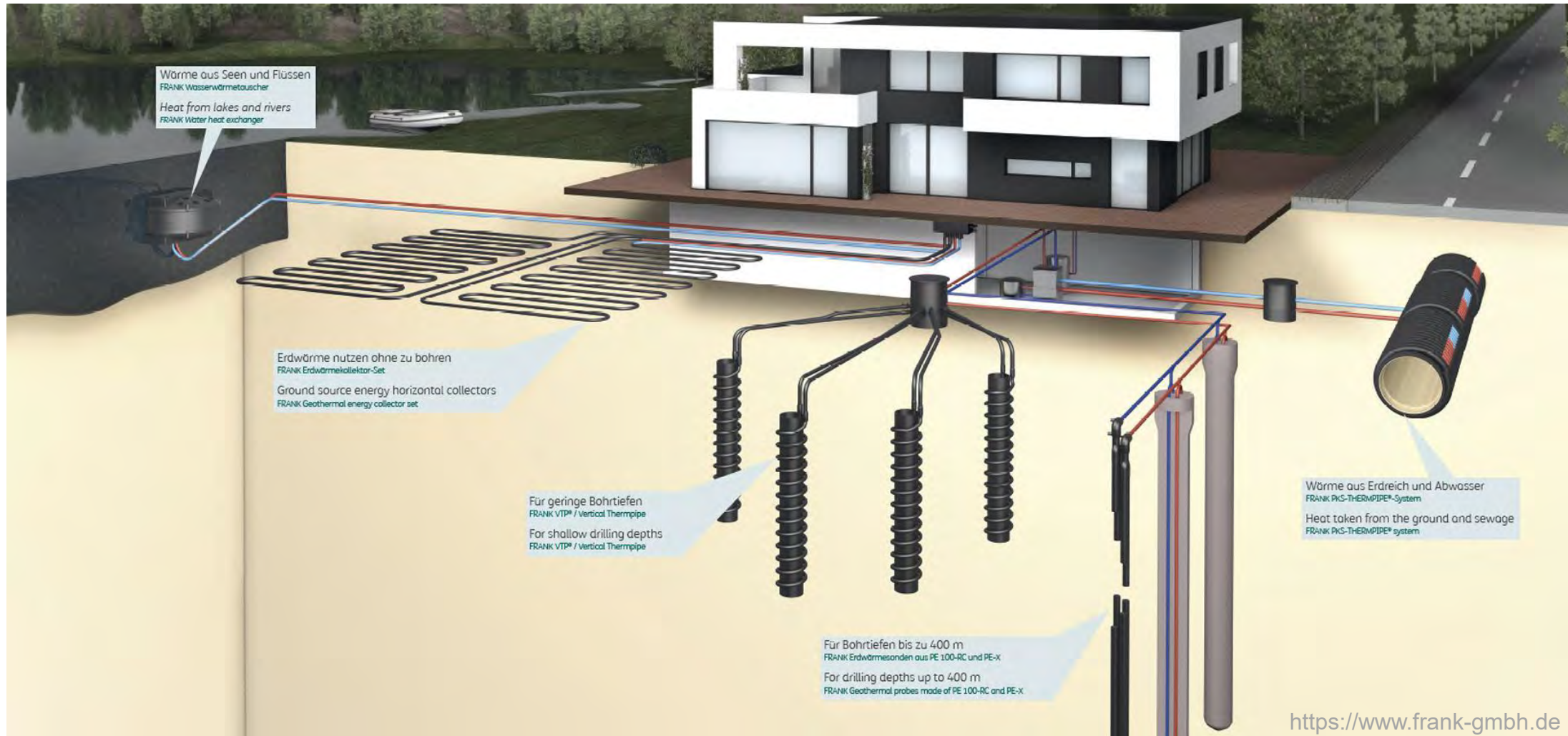
M. Scerbo, S. De Feudis, A. Insana, M. Barla – geosolving, Torino



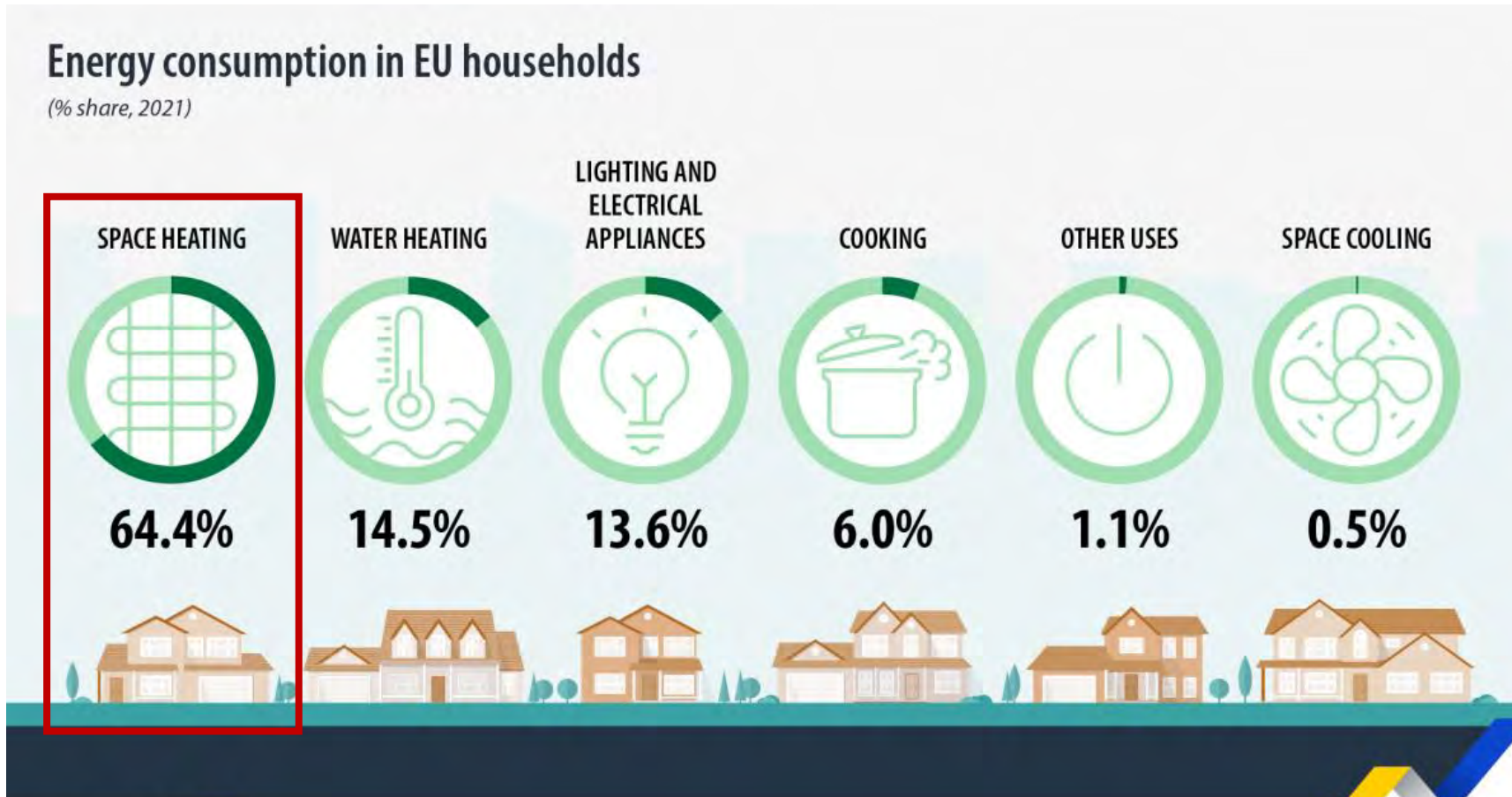
Polish Geological Institute  
National Research Institute

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

# GEO THERMAL ENERGY



# WHY GEOTHERMAL ENERGY?

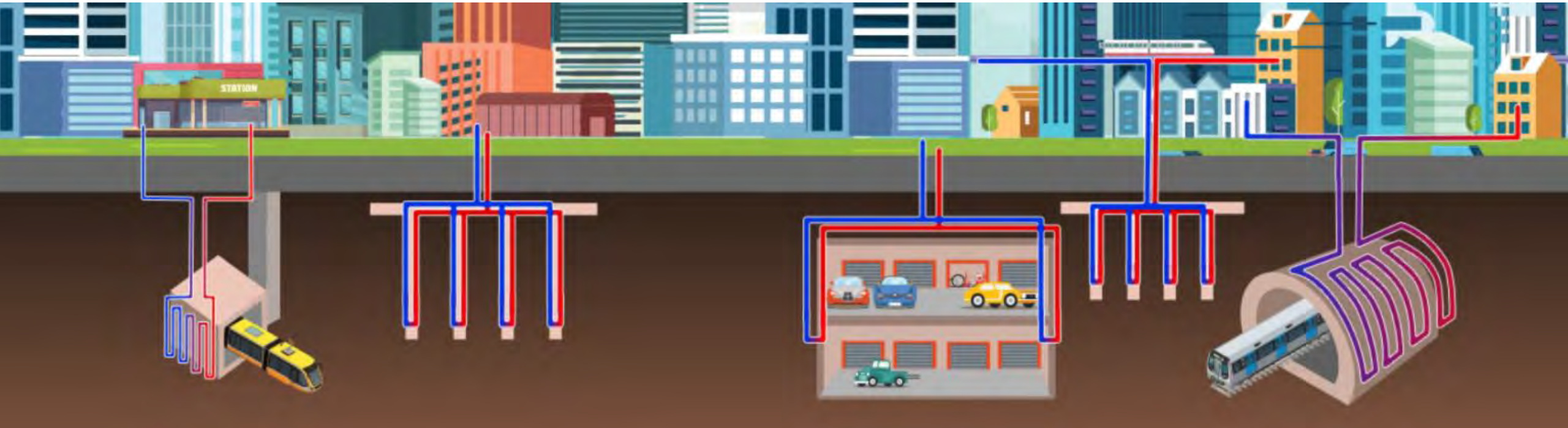


About 30% of the total energy consumption in Poland goes to the private households.

Thereof, 65% are used for heating.

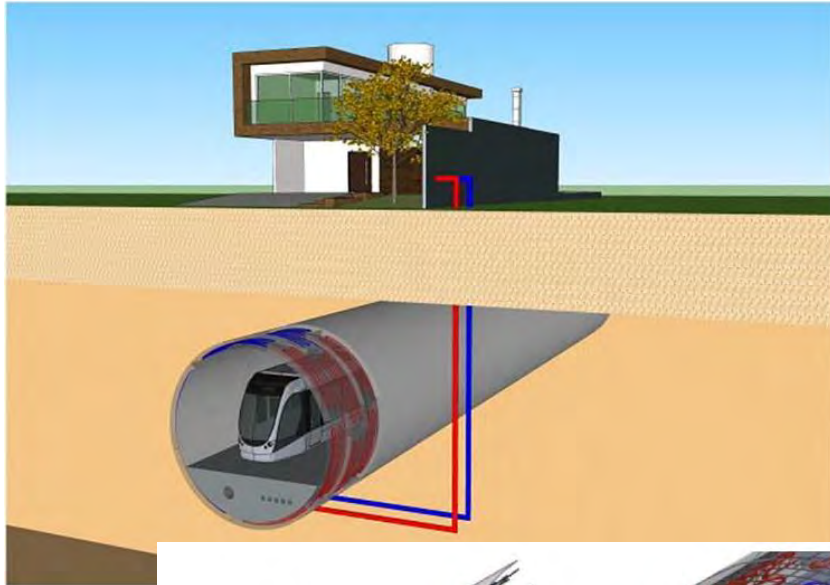
→ About 20% of the total energy consumption could be covered by geothermal energy

# ENERGY GEOSTRUCTURES

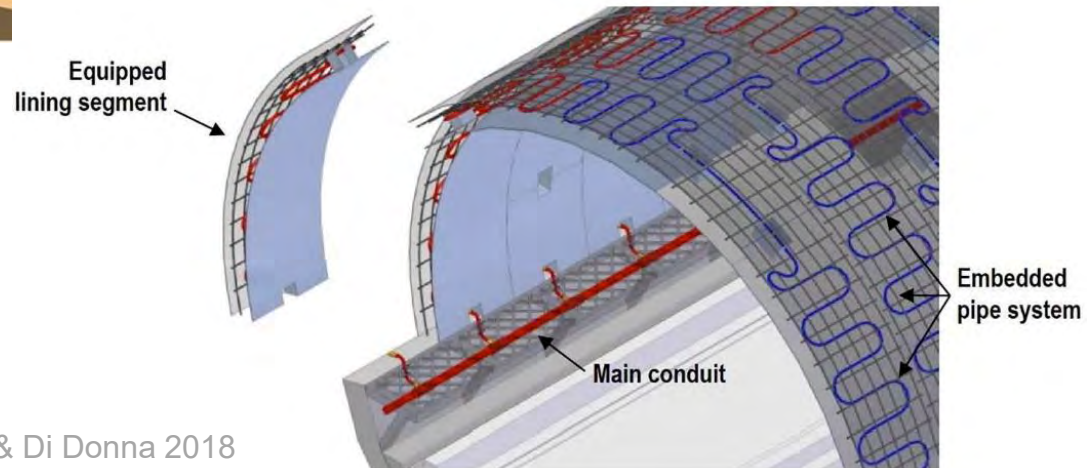


<https://www.ca-foilage.eu/>

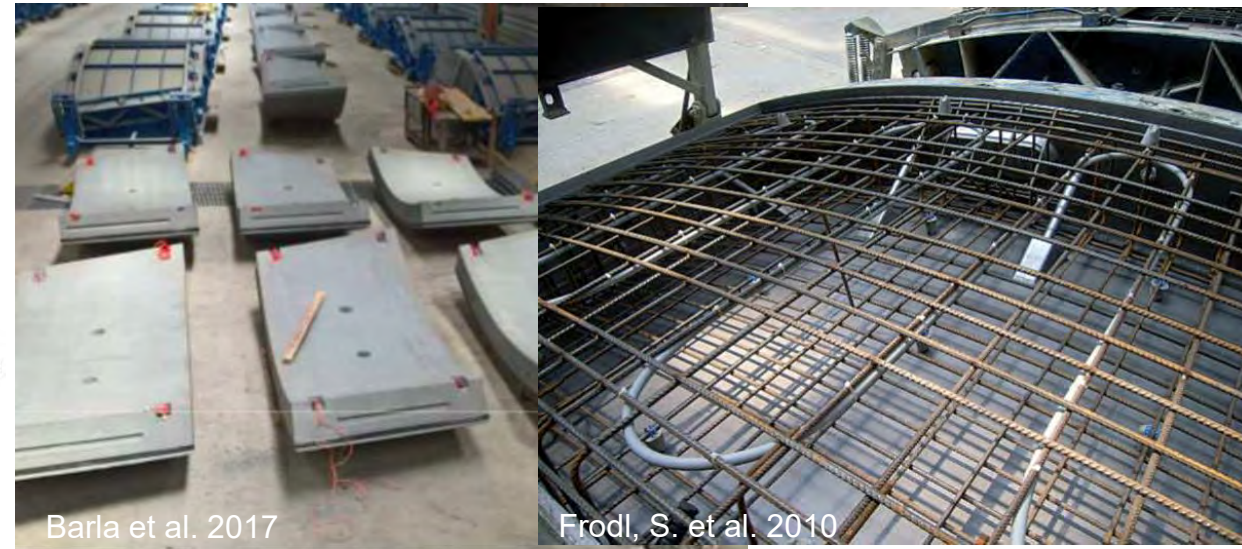
# ENERGY TUNNELS



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<sub>2</sub> neutral by 2040
- explore the energy potential
- and the technical feasibility
- for two projects in different geology



TECHNISCHE  
UNIVERSITÄT  
DARMSTADT



# STUDIES

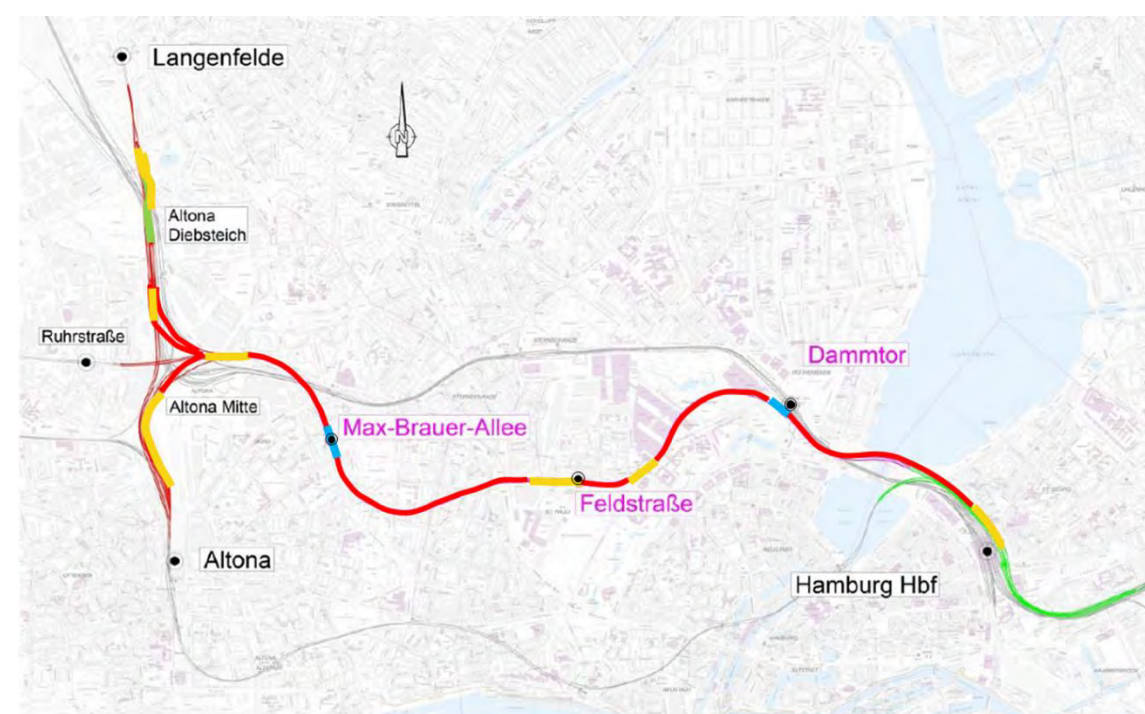
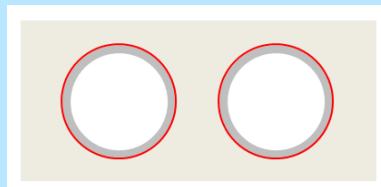
- Feasibility study for Deutsche Bahn (DB)
- DB aims to be CO<sub>2</sub> neutral by 2040
  - explore the energy potential
  - and the technical feasibility
  - for two projects in different geology

Location: **Hamburg**

Name: Verbindungsbahn-Entlastungstunnel

Length: approx. 12.8 km

Type: Twin Tunnel



# STUDIES

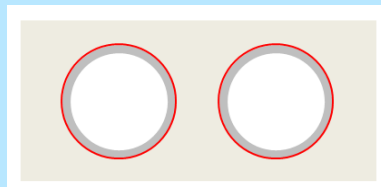
- Feasibility study for Deutsche Bahn (DB)
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Location: **Stuttgart**

Name: Pfaffensteigtunnel

Length: approx. 22.3 km

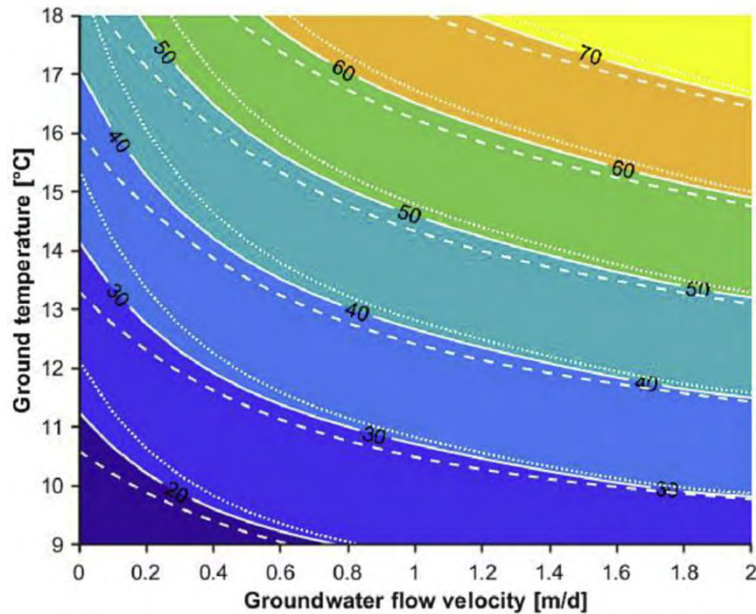
Type: Twin Tunnel



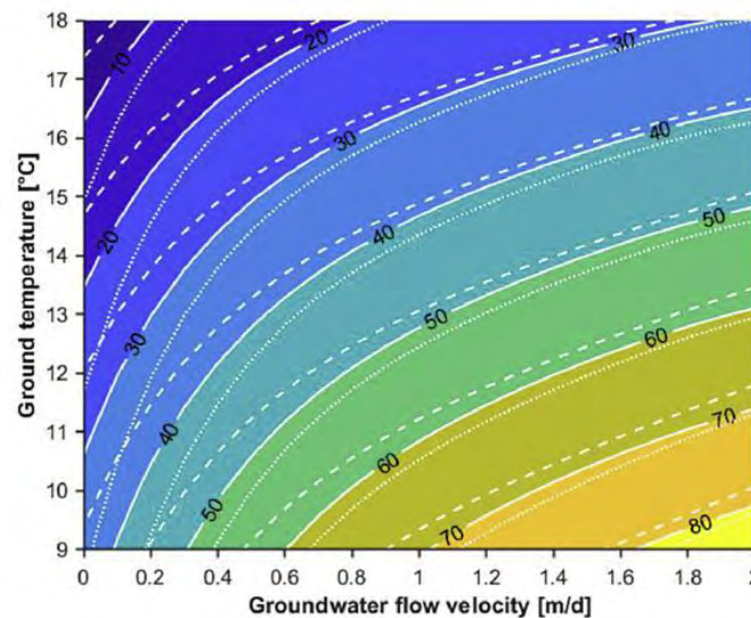
# POTENTIAL ANALYSIS

## Nomogram-approach by Insana et al. 2020

Winter (heating)  
Geothermal potential W/m<sup>2</sup>



Summer (cooling)  
Geothermal potential W/m<sup>2</sup>



.....  $\lambda=0.9$  W/mK    ———  $\lambda=2.26$  W/mK    - - -  $\lambda=3.9$  W/mK

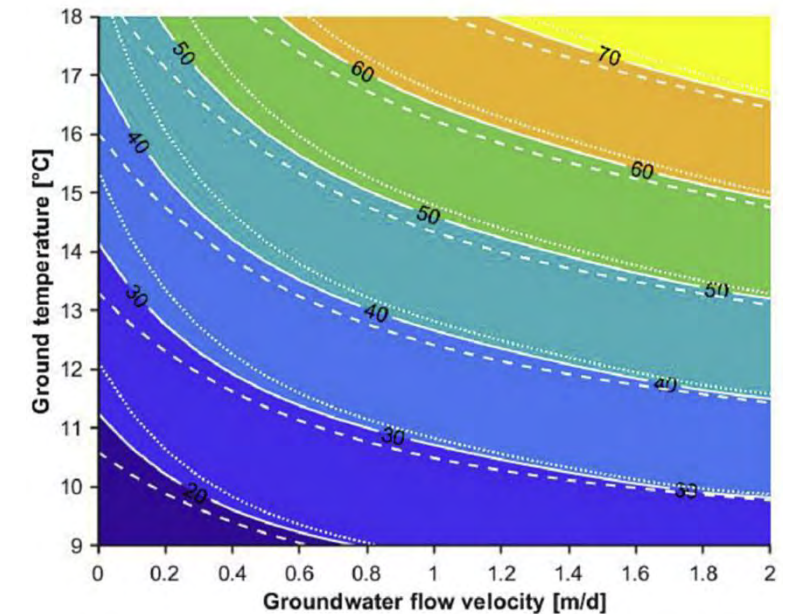
Main assumptions:

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

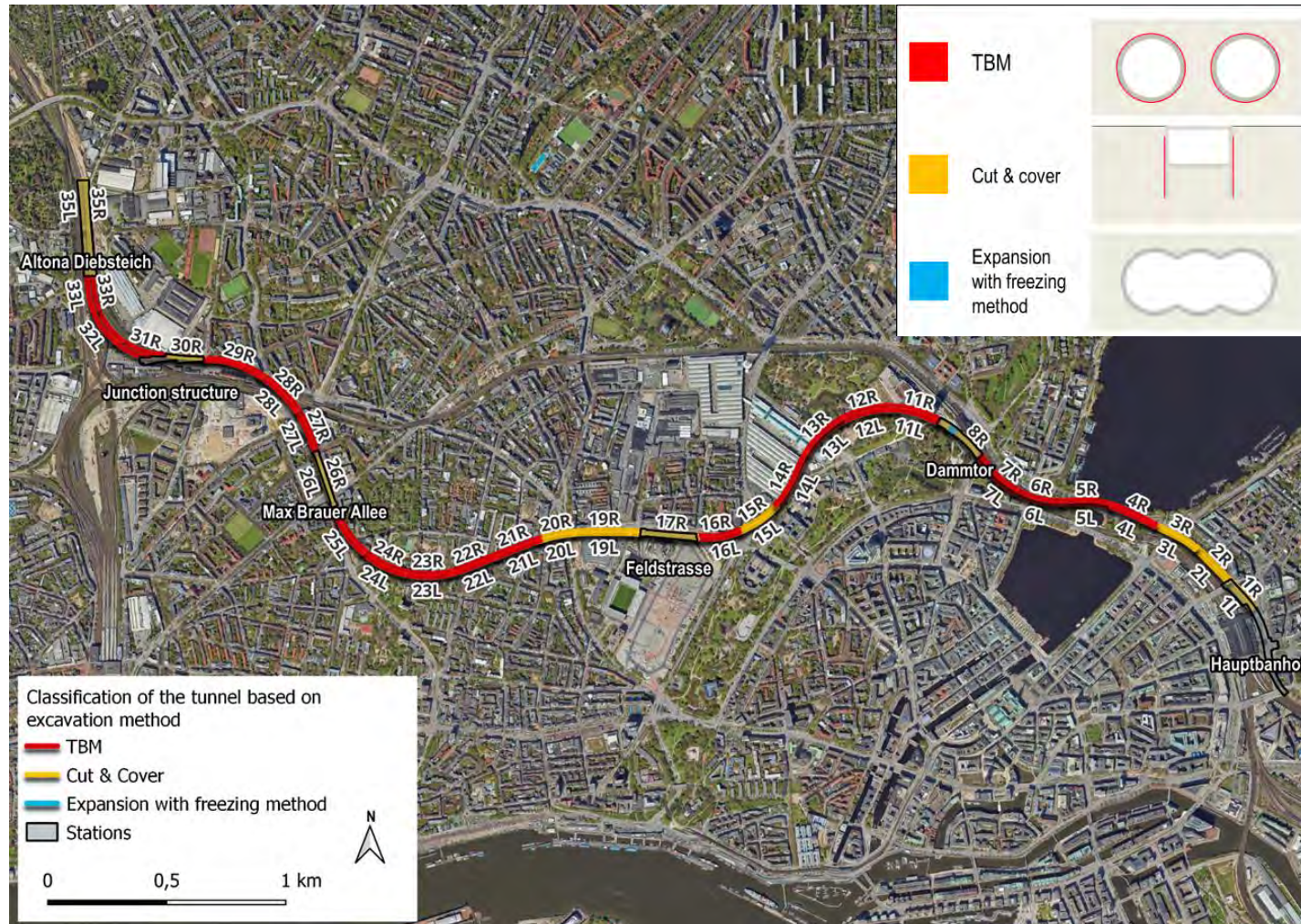
# POTENTIAL ANALYSIS

## Procedure

- Define tunnel sections with constant
  - Geology
  - Cross section
  - Groundwater flow
- Extract heating/cooling energy potential  $\text{W/m}^2$
- Here: update based on FE simulations due to twin tunnel

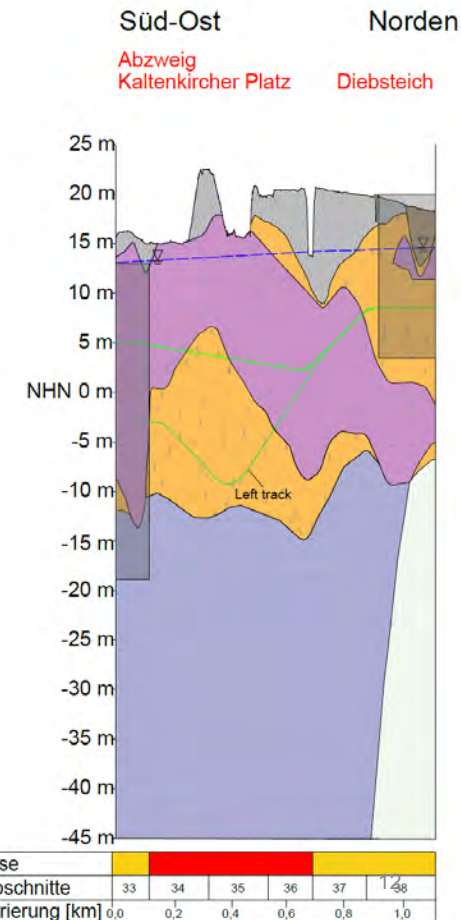
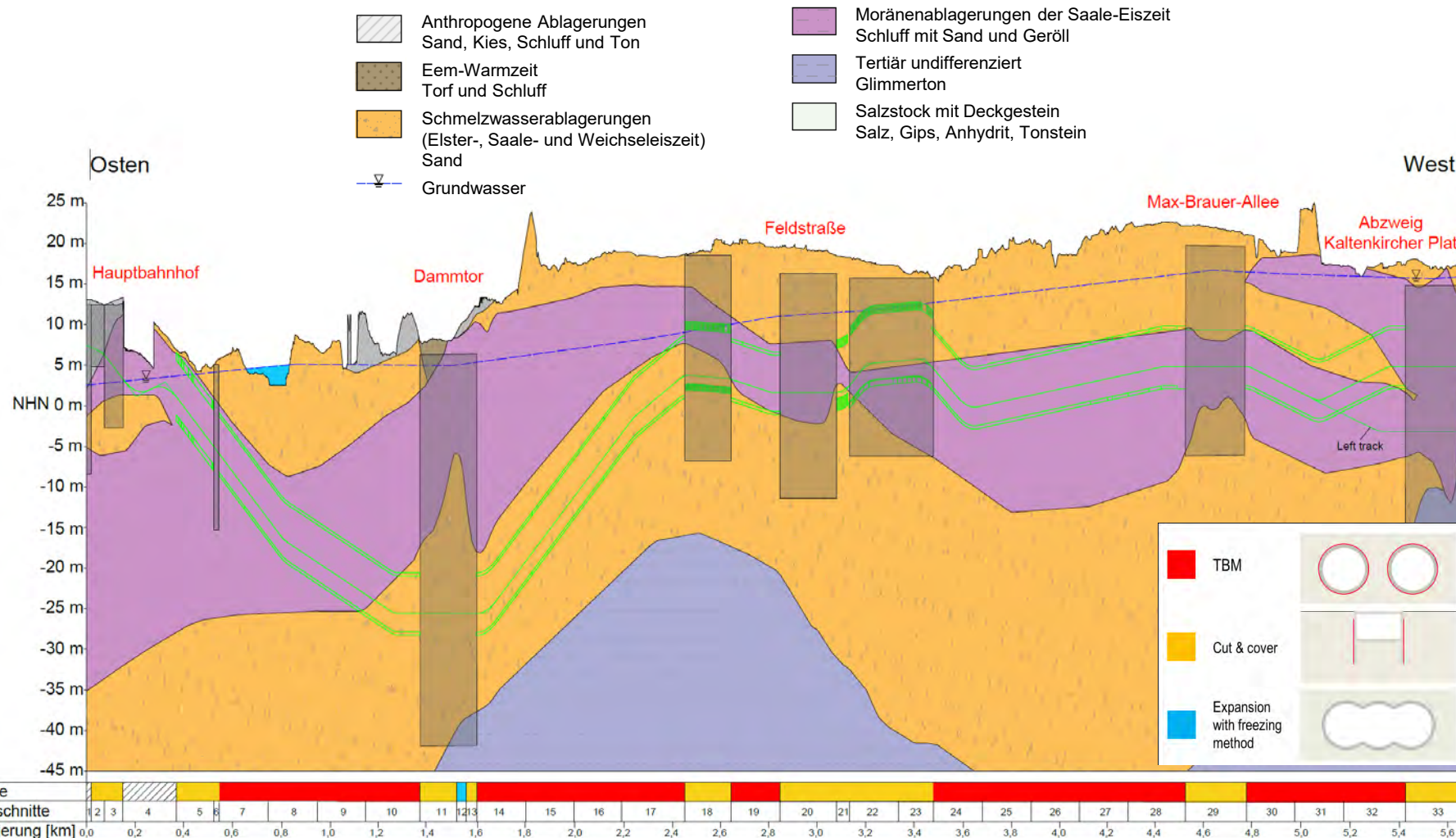


# HAMBURG – CROSS SECTIONS

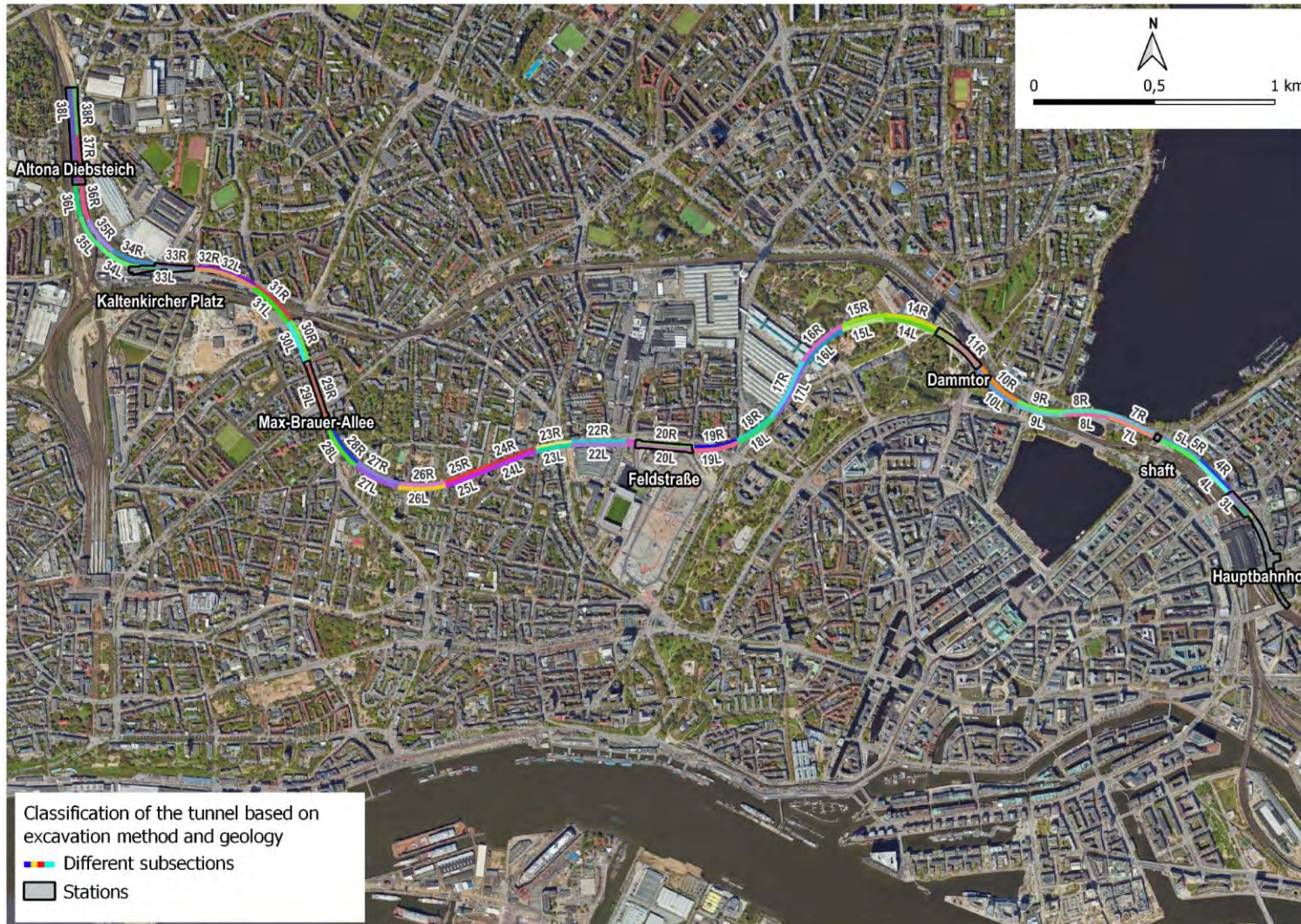


- Mainly Tunnel boring machine
- Stations in cut & cover
- Total tunnel length 12.8 km
- Preliminary tunnel route, not yet fixed!

# HAMBURG - GEOLOGY

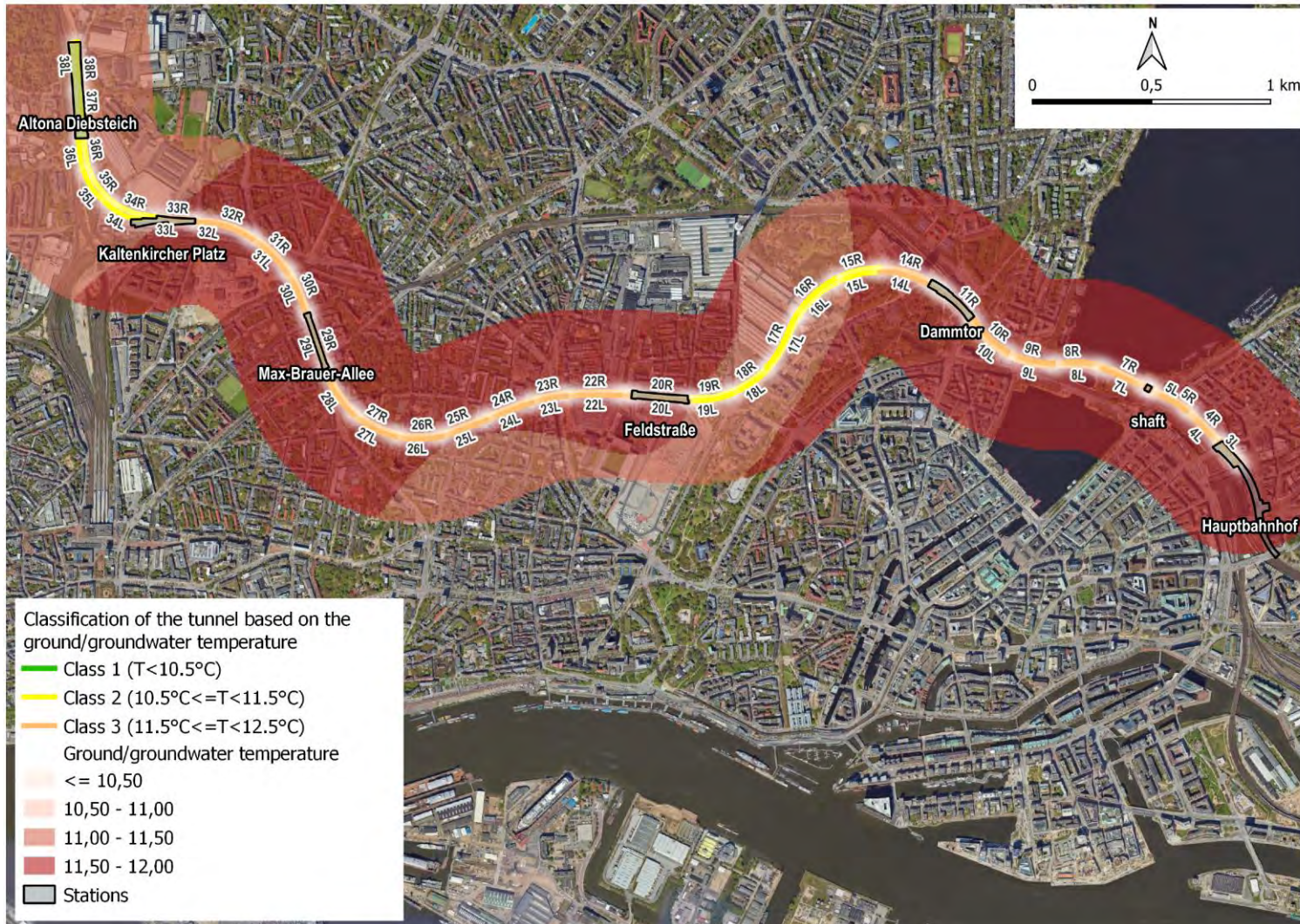


# HAMBURG – SUBSECTIONS



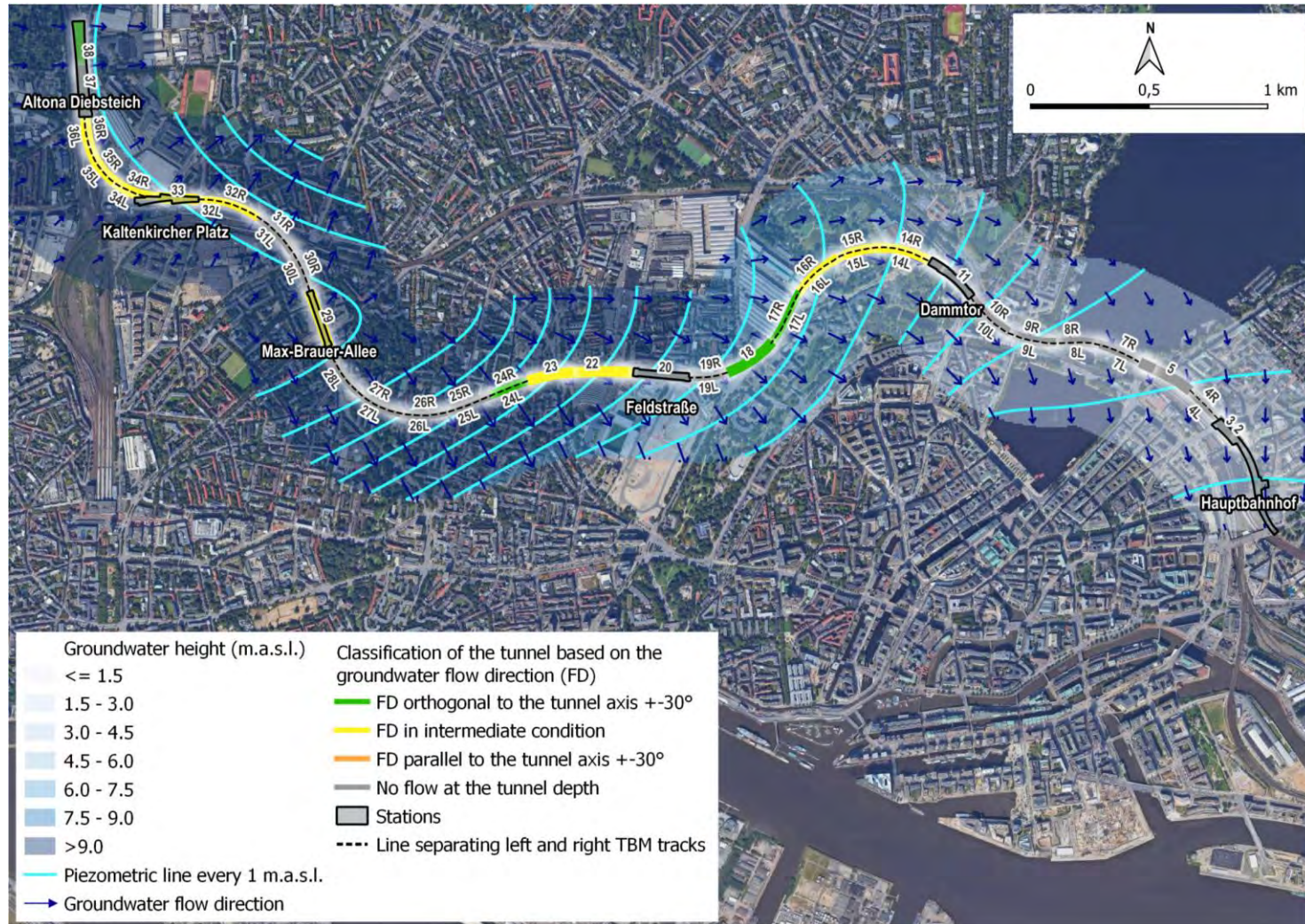
- Subsections with equal
  - Geology
  - Construction method
  - Hydrological conditions

# HAMBURG - TEMPERATURE



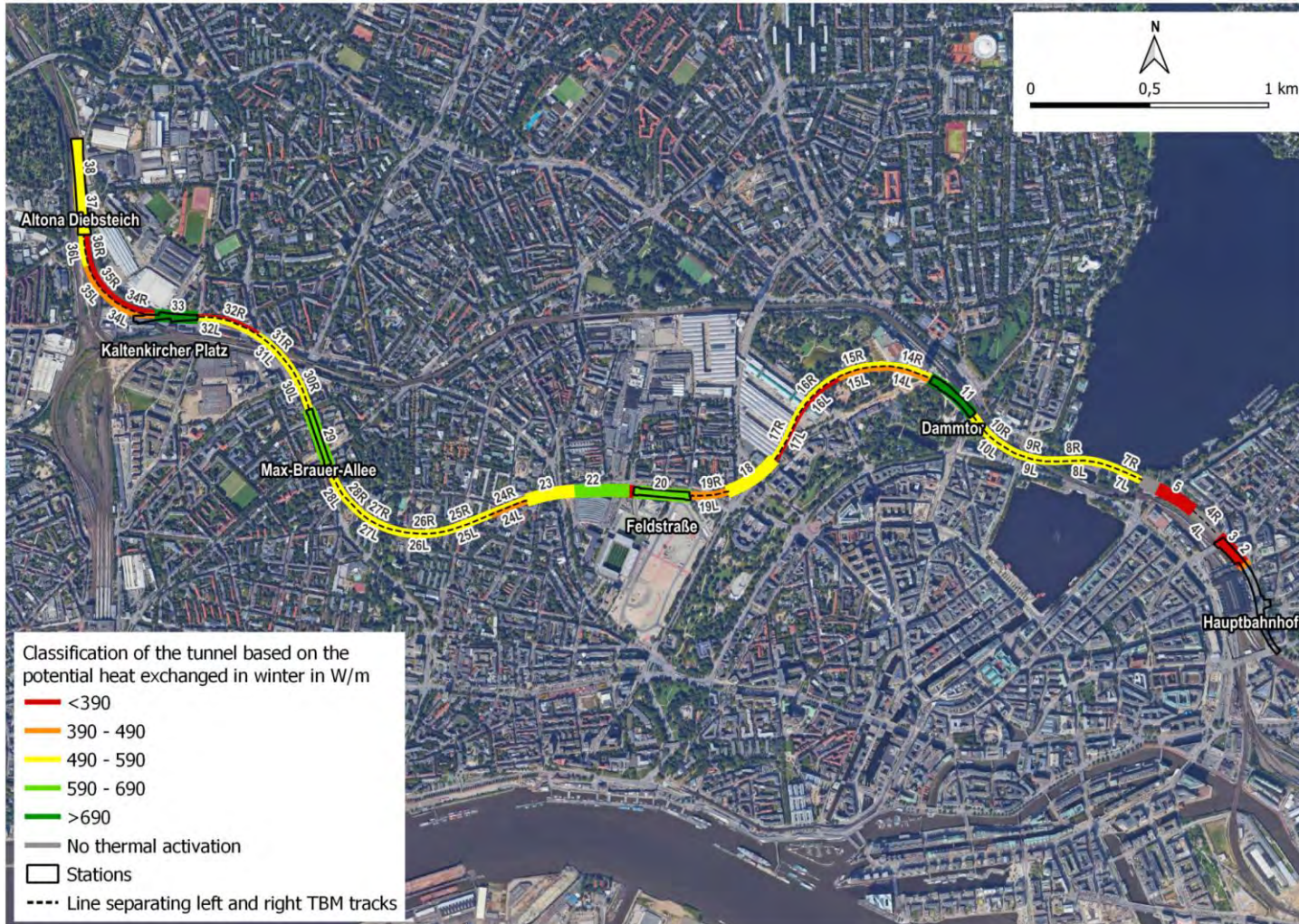
- Temperatures extracted from public data
- Assigned to the segments

# 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

		Empfehlener Segmentlänge in abstr. Längs		Empfehlener Segmentlänge in abstr. Längs	
		0,5		0,5	
		Summe: 6295		Summe: 5338,8	
		davon aktiv: 5416		davon aktiv: 4888,1	
				in abstr. Längs: 0,83	
				in abstr. Längs: 0,54	

Segment	Start (km)	Ende (km)	Energiepotenzial (W/m)	Energiepotenzial (W/m)	Nutzung über															
					Nutzung über 10 Jahre		Nutzung über 20 Jahre		Nutzung über 30 Jahre		Nutzung über 40 Jahre		Nutzung über 50 Jahre							
					PK	PK	PK	PK	PK	PK	PK	PK	PK	PK	PK	PK	PK	PK	PK	
1	0,00	20,50	Sonder	20,5	22	11	22	11	150,0	60,0	7,8	3,5	1020	60,0	0,3	0,2	7,0	3,5		
2	20,50	73,87	Offen	53,2	22	11	22	11	330,0	165,0	25,5	12,7	3300	165,0	0,4	0,4	20,5	12,7		
3	73,87	161,00	Offen	77,2	22	11	22	11	330,0	165,0	25,5	12,7	3300	165,0	0,4	0,4	20,5	12,7		
4	161,00	400,00	Sonder	239,0	22	11	22	11	330,0	165,0	25,5	12,7	3300	165,0	0,4	0,4	20,5	12,7		
5	400,00	524,04	Offen	124,04	21	10	21	10	300,0	150,0	22,5	11,2	3000	150,0	0,3	0,3	18,0	9,0		
6	524,04	544,65	Sonder	20,6	22	11	22	11	330,0	165,0	25,5	12,7	3300	165,0	0,4	0,4	20,5	12,7		
7	544,65	744,65	TBM	200,0	3	1	3	1	530,0	265,0	35,2	17,6	5300	265,0	1,0	0,9	35,2	17,6		
8	744,65	844,65	TBM	200,0	3	1	3	1	530,0	265,0	35,2	17,6	5300	265,0	1,0	0,9	35,2	17,6		
9	844,65	1144,65	TBM	200,0	3	1	3	1	530,0	265,0	35,2	17,6	5300	265,0	1,0	0,9	35,2	17,6		
10	1144,65	1373,65	TBM	229,0	4	2	4	2	561,0	280,5	37,4	18,7	5610	280,5	1,1	1,0	37,4	18,7		
11	1373,65	1520,18	Offen	146,5	22	11	22	11	330,0	165,0	25,5	12,7	3300	165,0	0,4	0,4	20,5	12,7		
12	1520,18	1600,00	Offen	79,8	22	11	22	11	330,0	165,0	25,5	12,7	3300	165,0	0,4	0,4	20,5	12,7		
13	1600,00	1800,00	TBM	200,0	3	1	3	1	530,0	265,0	35,2	17,6	5300	265,0	1,0	0,9	35,2	17,6		
14	1800,00	2005,00	TBM	200,0	3	1	3	1	530,0	265,0	35,2	17,6	5300	265,0	1,0	0,9	35,2	17,6		
15	2005,00	2205,00	TBM	200,0	3	1	3	1	530,0	265,0	35,2	17,6	5300	265,0	1,0	0,9	35,2	17,6		
16	2205,00	2470,25	TBM	265,25	9	4	9	4	605,25	302,6	40,3	20,1	6052,5	302,6	1,2	1,1	40,3	20,1		
17	2470,25	2665,00	TBM	194,75	24	12	24	12	1177,25	588,6	78,9	39,4	11772,5	588,6	3,0	2,9	78,9	39,4		
18	2665,00	2858,00	TBM	193,0	19	9	19	9	605,25	302,6	40,3	20,1	6052,5	302,6	1,2	1,1	40,3	20,1		
19	2858,00	3093,00	Offen	235,0	21	10	21	10	330,0	165,0	25,5	12,7	3300	165,0	0,4	0,4	20,5	12,7		
20	3093,00	3334,60	Offen	241,6	22	11	22	11	330,0	165,0	25,5	12,7	3300	165,0	0,4	0,4	20,5	12,7		
21	3334,60	3479,00	Offen	144,4	12	6	12	6	330,0	165,0	25,5	12,7	3300	165,0	0,4	0,4	20,5	12,7		
22	3479,00	3679,60	TBM	200,0	3	1	3	1	530,0	265,0	35,2	17,6	5300	265,0	1,0	0,9	35,2	17,6		
23	3679,60	3879,60	TBM	200,0	3	1	3	1	530,0	265,0	35,2	17,6	5300	265,0	1,0	0,9	35,2	17,6		
24	3879,60	4079,60	TBM	200,0	3	1	3	1	530,0	265,0	35,2	17,6	5300	265,0	1,0	0,9	35,2	17,6		
25	4079,60	4279,60	TBM	200,0	3	1	3	1	530,0	265,0	35,2	17,6	5300	265,0	1,0	0,9	35,2	17,6		
26	4279,60	4450,00	TBM	170,4	3	1	3	1	530,0	265,0	35,2	17,6	5300	265,0	1,0	0,9	35,2	17,6		
27	4450,00	4777,00	Offen	327,0	26	13	26	13	1143,8	571,9	76,9	38,4	11438	571,9	3,0	2,9	76,9	38,4		
28	4777,00	4977,00	TBM	200,0	3	1	3	1	530,0	265,0	35,2	17,6	5300	265,0	1,0	0,9	35,2	17,6		
29	4977,00	5177,00	TBM	200,0	3	1	3	1	530,0	265,0	35,2	17,6	5300	265,0	1,0	0,9	35,2	17,6		
30	5177,00	5432,00	TBM	255,0	6	3	6	3	791,8	395,9	52,6	26,3	7918	395,9	1,3	1,2	52,6	26,3		
31	5432,00	5700,70	Offen	268,7	26	13	26	13	1400,0	700,0	93,3	46,6	14000	700,0	3,2	3,1	93,3	46,6		
32	5700,70	6120,00	TBM	419,3	16	8	16	8	791,8	395,9	52,6	26,3	7918	395,9	1,3	1,2	52,6	26,3		
33	6120,00	6420,00	TBM	300,0	10	5	10	5	791,8	395,9	52,6	26,3	7918	395,9	1,3	1,2	52,6	26,3		
34	6420,00	6877,50	Offen	457,5	22	11	22	11	1312,8	656,4	87,5	43,7	13128	656,4	3,0	2,9	87,5	43,7		
35	6877,50	7100,00	Offen	222,5	19	9	19	9	1312,8	656,4	87,5	43,7	13128	656,4	3,0	2,9	87,5	43,7		
36	7100,00	7400,00	Offen	300,0	23	11	23	11	1312,8	656,4	87,5	43,7	13128	656,4	3,0	2,9	87,5	43,7		
37	7400,00	7600,00	Offen	200,0	16	8	16	8	1312,8	656,4	87,5	43,7	13128	656,4	3,0	2,9	87,5	43,7		
38	7600,00	7800,00	Offen	200,0	16	8	16	8	1312,8	656,4	87,5	43,7	13128	656,4	3,0	2,9	87,5	43,7		
39	7800,00	8000,00	Offen	200,0	16	8	16	8	1312,8	656,4	87,5	43,7	13128	656,4	3,0	2,9	87,5	43,7		
40	8000,00	8200,00	Offen	200,0	16	8	16	8	1312,8	656,4	87,5	43,7	13128	656,4	3,0	2,9	87,5	43,7		
41	8200,00	8400,00	Offen	200,0	16	8	16	8	1312,8	656,4	87,5	43,7	13128	656,4	3,0	2,9	87,5	43,7		
42	8400,00	8600,00	Offen	200,0	16	8	16	8	1312,8	656,4	87,5	43,7	13128	656,4	3,0	2,9	87,5	43,7		
43	8600,00	8800,00	Offen	200,0	16	8	16	8	1312,8	656,4	87,5	43,7	13128	656,4	3,0	2,9	87,5	43,7		
44	8800,00	9000,00	Offen	200,0	16	8	16	8	1312,8	656,4	87,5	43,7	13128	656,4	3,0	2,9	87,5	43,7		
45	9000,00	9200,00	Offen	200,0	16	8	16	8	1312,8	656,4	87,5	43,7	13128	656,4	3,0	2,9	87,5	43,7		
46	9200,00	9400,00	Offen	200,0	16	8	16	8	1312,8	656,4	87,5	43,7	13128	656,4	3,0	2,9	87,5	43,7		
47	9400,00	9600,00	Offen	200,0	16	8	16	8	1312,8	656,4	87,5	43,7	13128	656,4	3,0	2,9	87,5	43,7		
48	9600,00	9800,00	Offen	200,0	16	8	16	8	1312,8	656,4	87,5	43,7	13128	656,4	3,0	2,9	87,5	43,7		
49	9800,00	10000,00	Offen	200,0	16	8	16	8	1312,8	656,4	87,5	43,7	13128	656,4	3,0	2,9	87,5	43,7		
50	10000,00	10200,00	Offen	200,0	16	8	16	8	1312,8	656,4	87,5	43,7	13128	656,4	3,0	2,9	87,5	43,7		

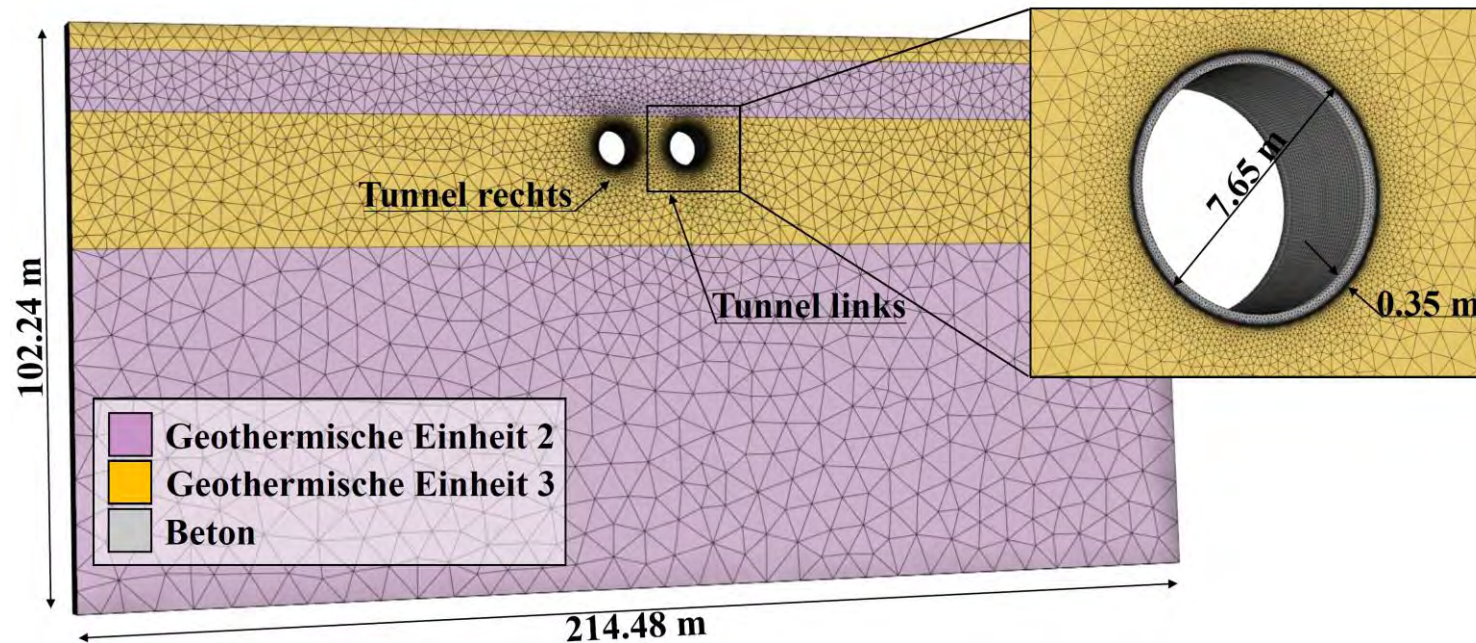
# STUTT GART

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

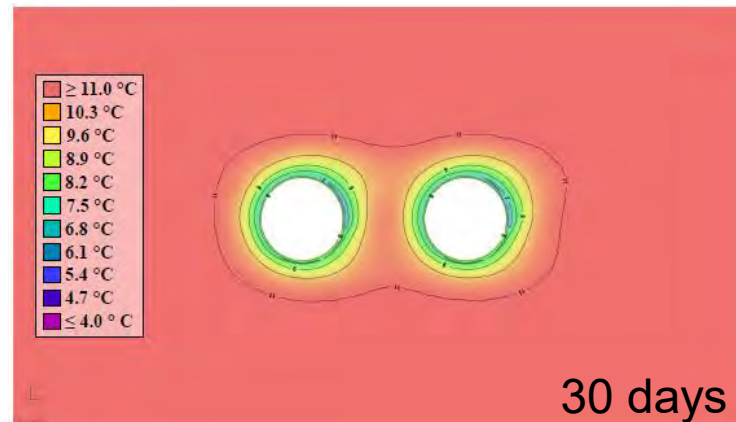


# NUMERICAL SIMULATIONS

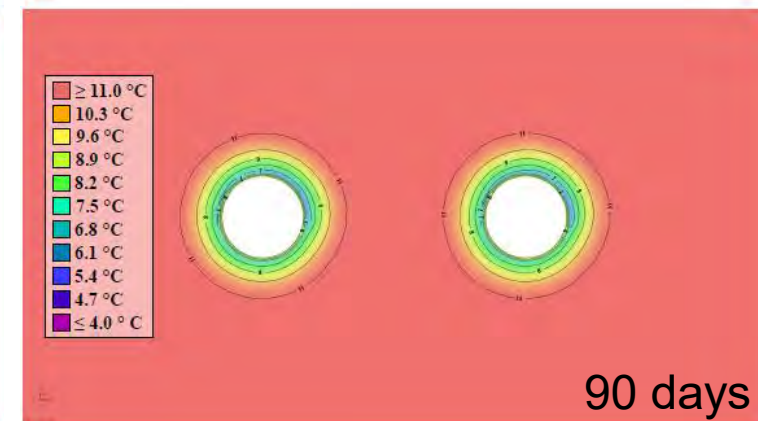
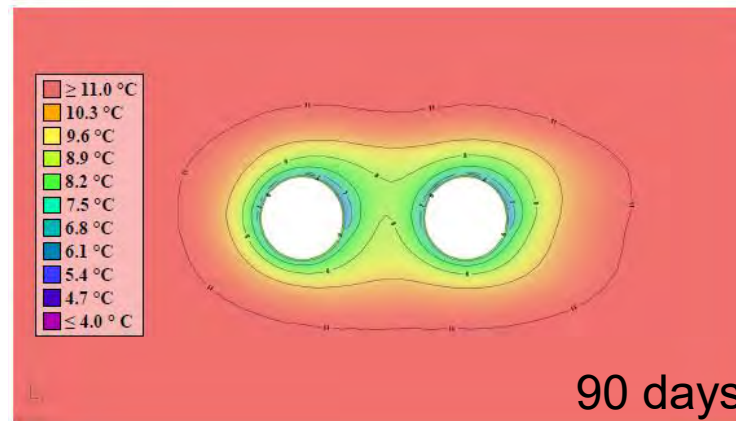
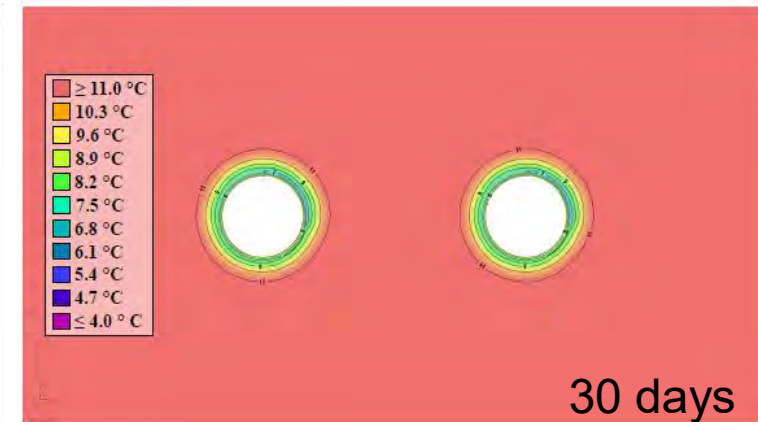
Findings:

- Interaction in Hamburg
- No interaction in Stuttgart

Hamburg - Winter



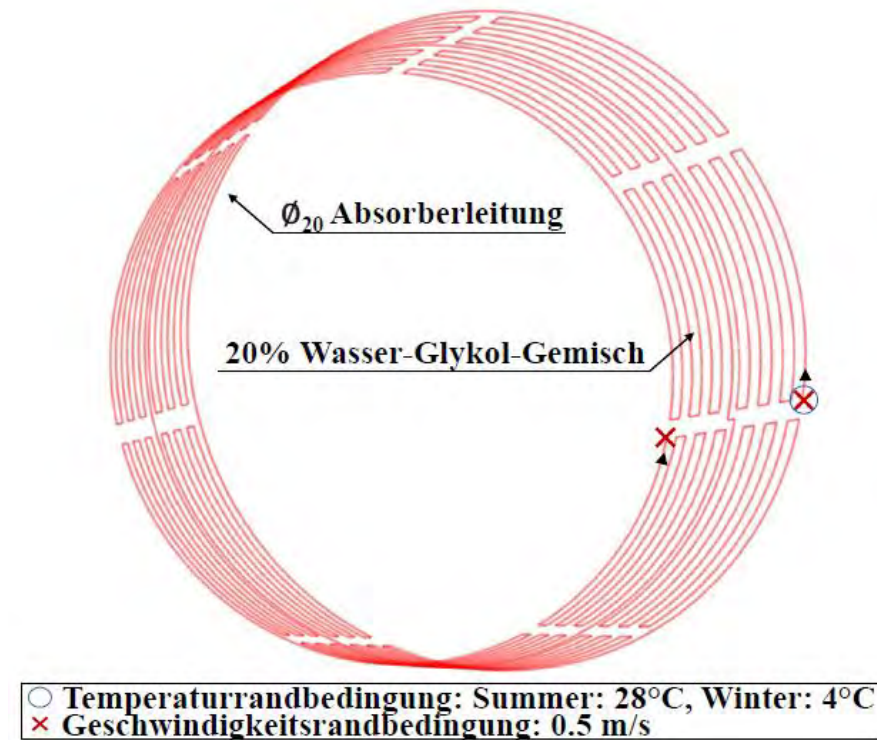
Stuttgart - Winter




# 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	confidential	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		





# THANK YOU FOR YOUR ATTENTION

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