

1. radionica PLIGES projekta

Projektne aktivnosti pri razradi sustava s većim brojem bušotinskih izmjenjivača topline



Marija Macenić



FERIT Osijek, 10.11.2023.



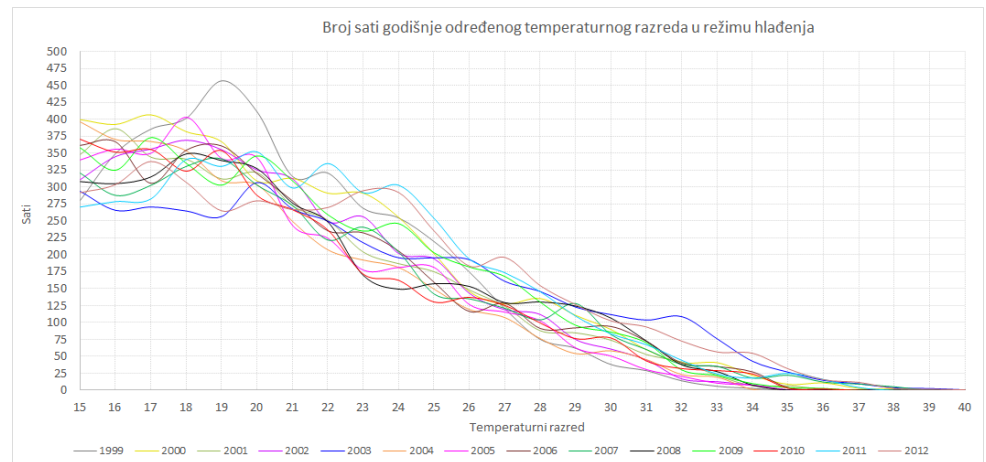
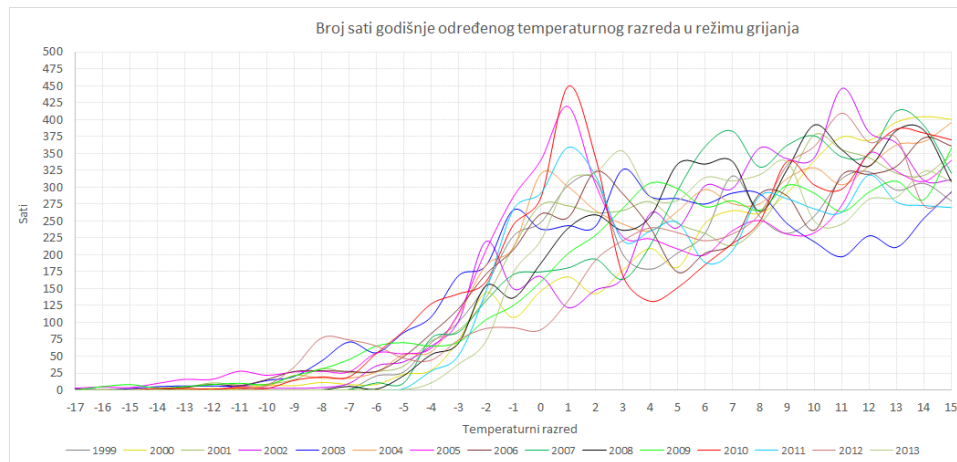
1. Uvod
2. Terra Negra Hotel, Čepin
3. IMI - Institut za medicinska istraživanja i medicinu rada, Zagreb
4. re-GENERATOR – Centar urbane kulture, Zabok
5. Designer Outlet, Zagreb
6. Dvorac Miljana, Poljana Sutlanska

2. Terra Negra Hotel, Čepin

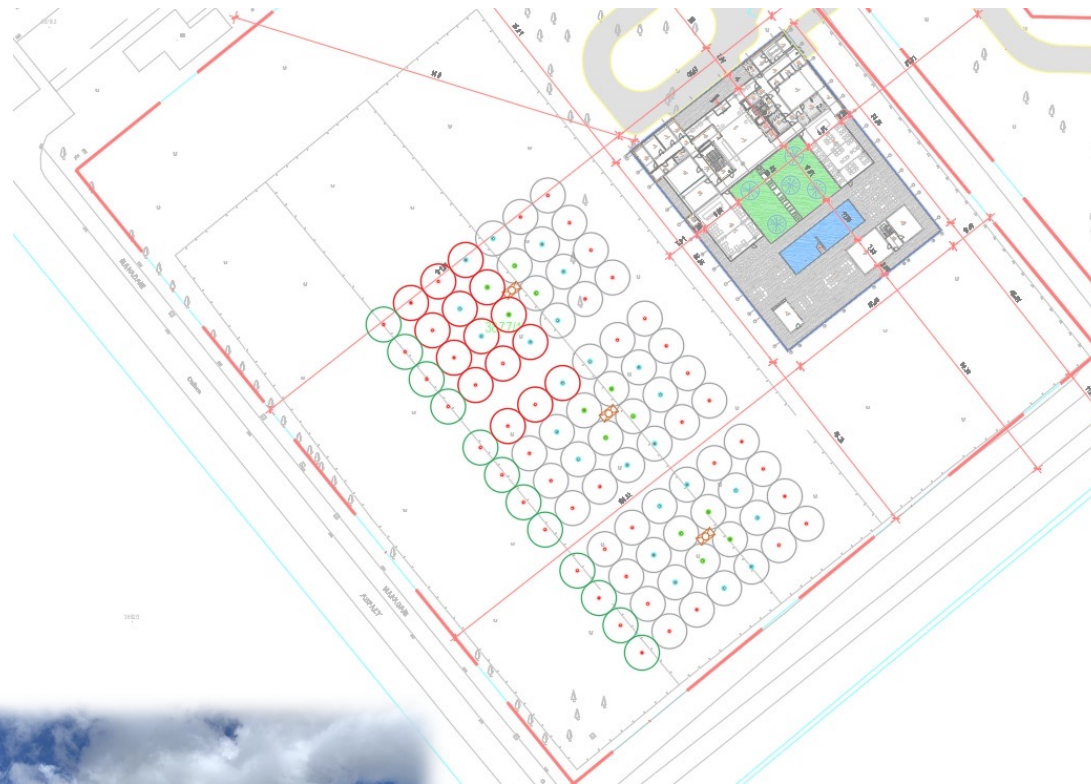
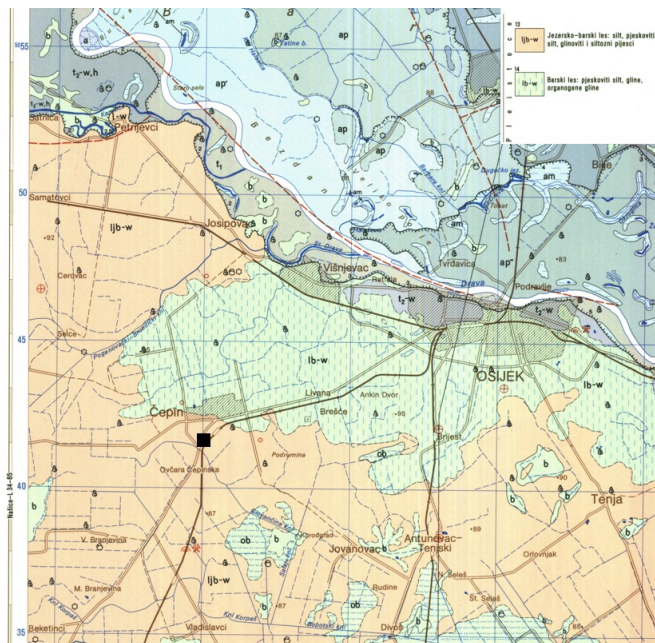


2. Terra Negra Hotel, Čepin

Mjesec	Srednja temp., C	Temp. percentil, p1	Temp. percentil, p99	Cooling factor energy	Cooling factor load	Energy cooling, kWhf	Cooling load, kWf	Energy heating + DHW, kWhf	Heating load, kWf	Heating factor energy	Heating factor load	DHW
1	-0,8	-13,7	9,9	0,000	0,000	0	0,0	193.536	576,0	0,2800	0,493	5000
2	1,9	-10,8	11,6	0,000	0,000	0	0,0	117.504	444,3	0,1700	0,451	5000
3	5,9	-6,1	14,5	0,000	0,000	0	0,0	62.208	376,5	0,0900	0,382	5000
4	10,6	3,0	18,6	0,038	0,308	13.859	149,6	15.206	245,2	0,0220	0,249	5000
5	15,3	6,9	22,2	0,157	0,615	57.258	299,2	0	0,0	0,0000	0,000	5000
6	18,5	10,6	25,0	0,211	0,855	76.952	415,5	0	0,0	0,0000	0,000	5000
7	20,1	13,0	26,7	0,220	1,000	80.234	521,0	0	0,0	0,0000	0,000	5000
8	19,3	12,6	25,7	0,218	0,915	79.505	444,6	0	0,0	0,0000	0,000	5000
9	15,8	8,8	23,0	0,156	0,684	56.893	332,4	17.280	161,6	0,0250	0,000	5000
10	10,5	2,2	18,0	0,000	0,000	0	0,0	26.266	256,8	0,0380	0,261	5000
11	5,3	-4,6	15,9	0,000	0,000	0	0,0	86.400	354,9	0,1250	0,360	5000
12	0,9	-9,2	12,5	0,000	0,000	0	0,0	172.800	421,2	0,2500	0,427	5000
				1,000		364.700		691.200		1,0000		60000



2. Terra Negra Hotel, Čepin



72 bušotine x 120 m

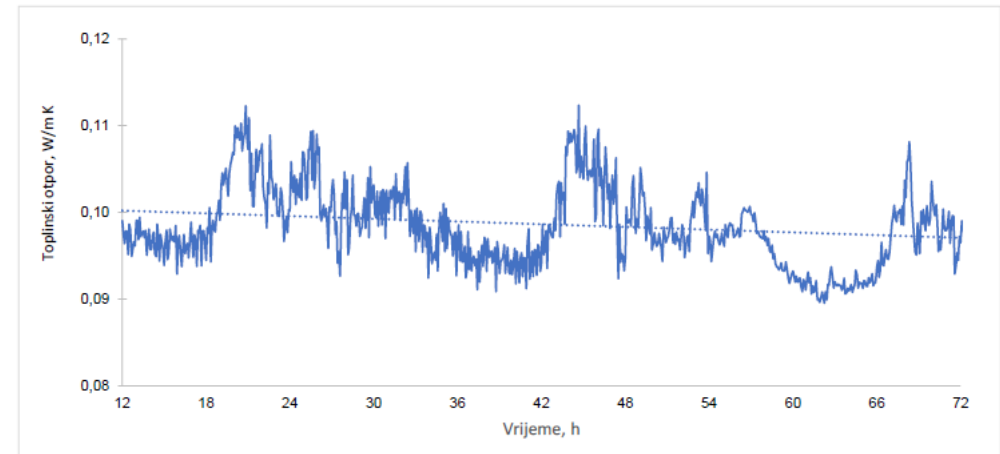
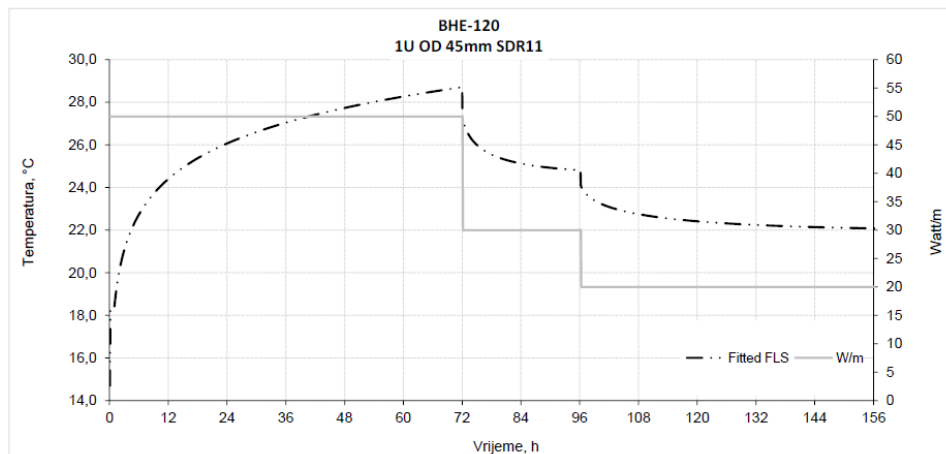
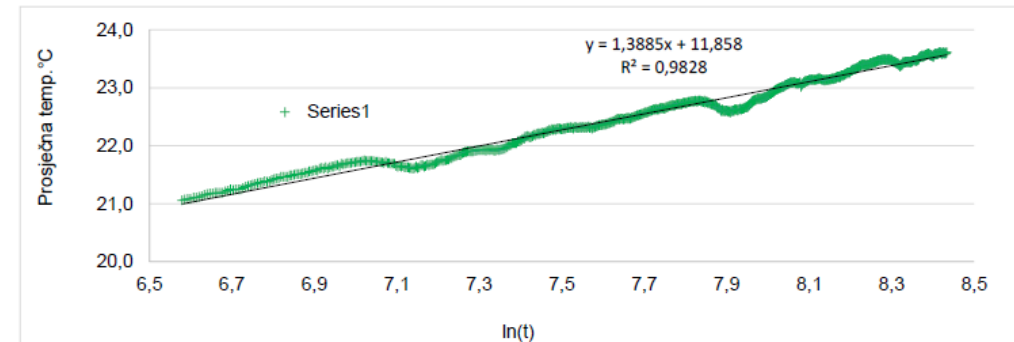
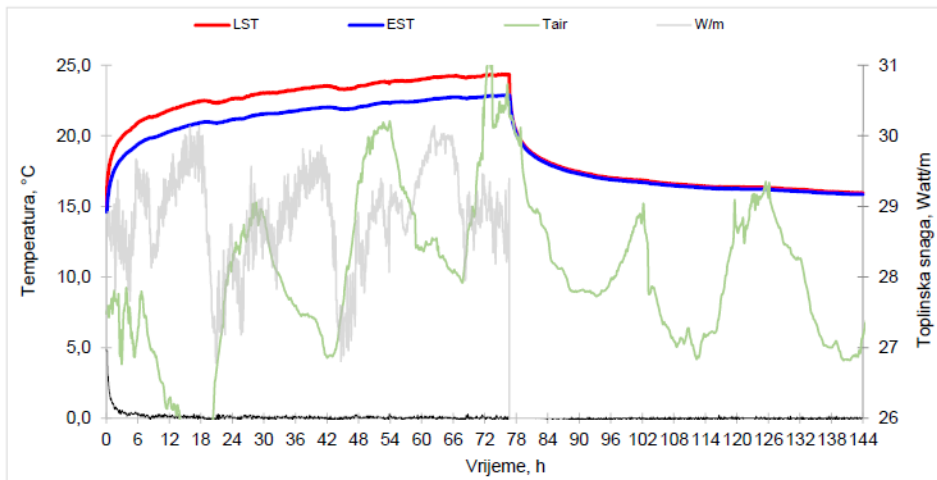
15 bušotina x 120 m

69 bušotina x 100 m

8700 m bušotinskih izmjenjivača

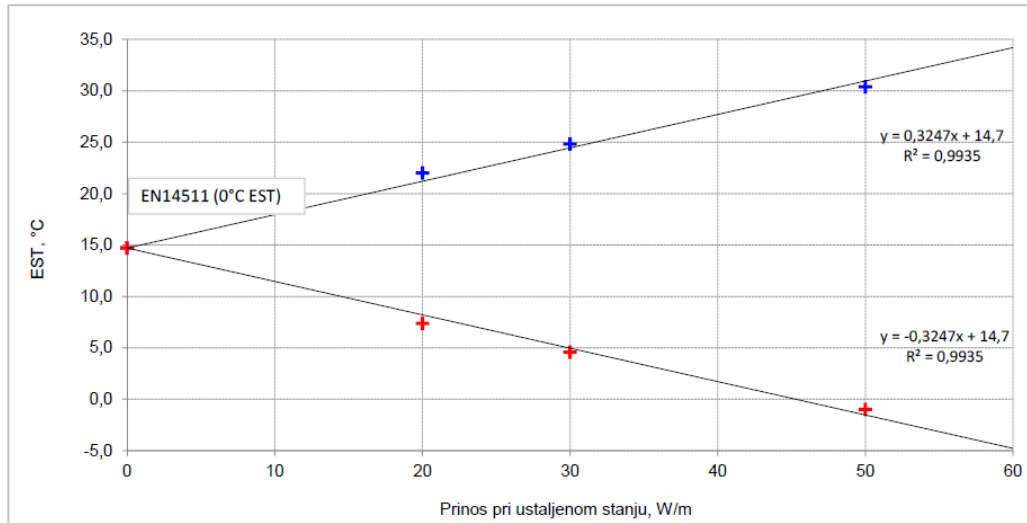
2. Terra Negra Hotel, Čepin

- Test toplinskog odaziva – nužnost kod svakog sustava
- 2 testne bušotine: 120 m – TRT – 1,65 W/m K; 100 m – TRT – 1,73 W/m K

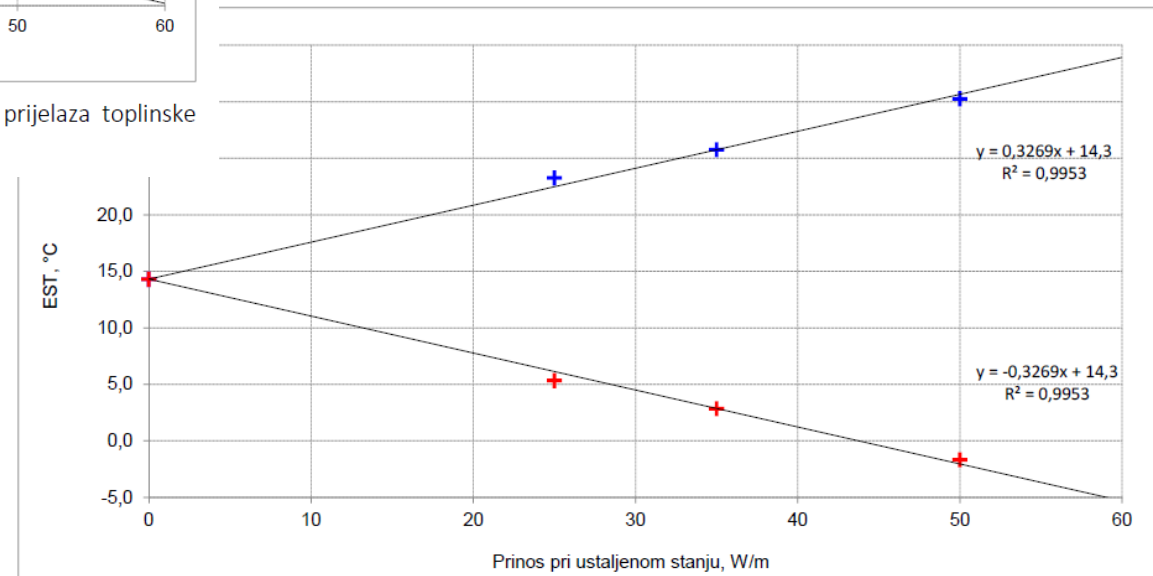


2. Terra Negra Hotel, Čepin

- Prinos bušotine



Slika 3-5. Rezultat analize kapaciteta davanja BHE-120 pri ustaljenom stanju prijelaza toplinske energije grijanja i hlađenja i izlazne temperature fluida iz bušotine

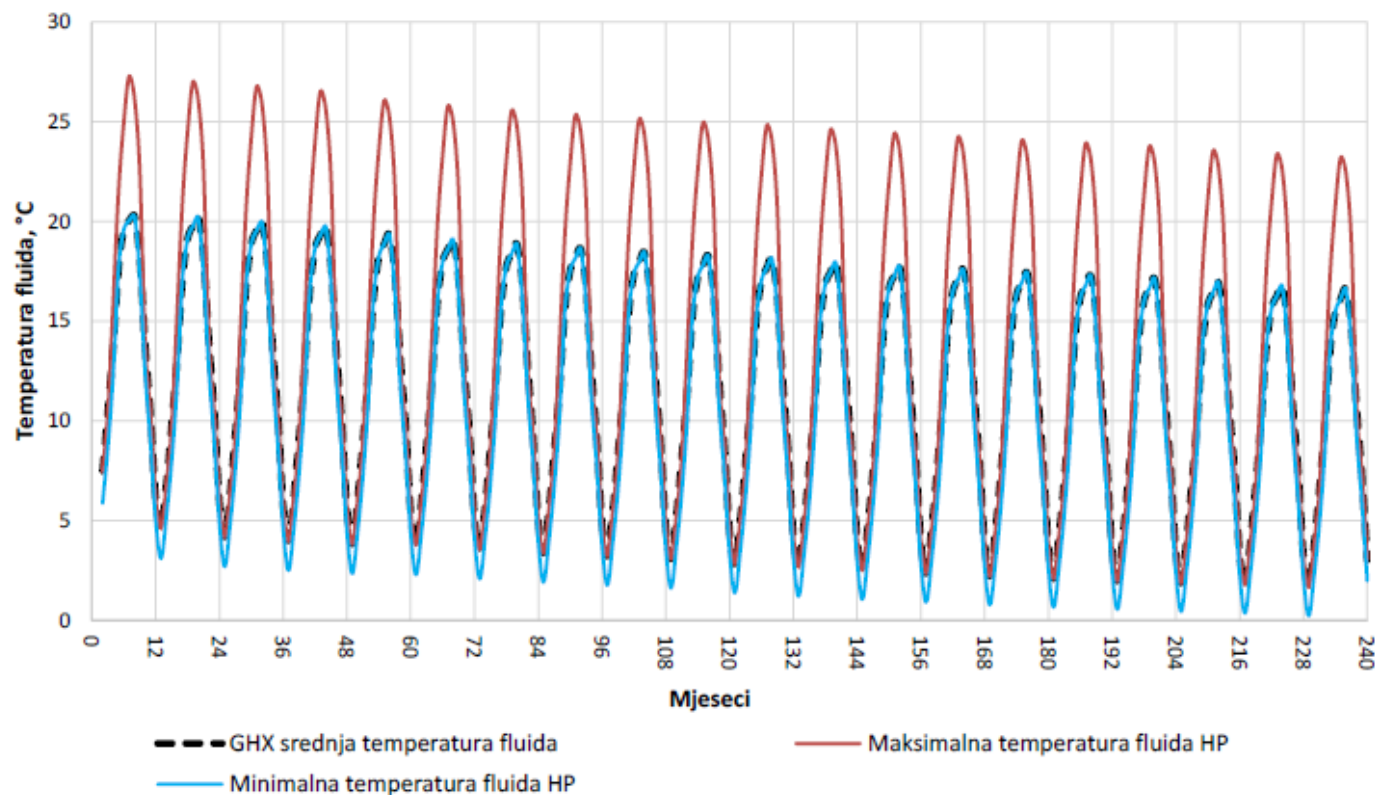


Slika 4-5. Rezultat analize kapaciteta davanja BHE-100 pri ustaljenom stanju prijelaza toplinske energije grijanja i hlađenja i izlazne temperature fluida iz bušotine

2. Terra Negra Hotel, Čepin

- Predikcija rada sustava – 20 godina

Rezultat simulacije kretanja bušotinske temperature u GLD/GHX programskim paketima za 20 godina:



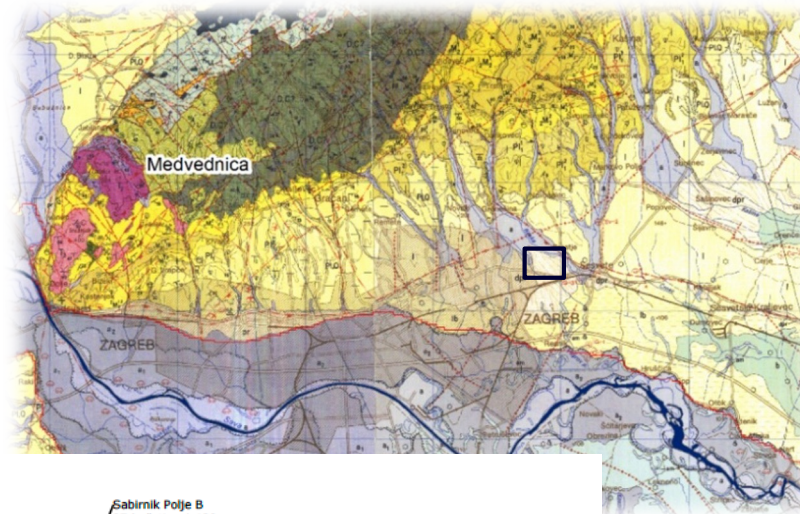
3. IMI - Institut za medicinska istraživanja i medicinu rada, Zagreb

- 5 katova, 5 000 m² površina, završeno 2022.g.
- GSHP – grijanje i hlađenje



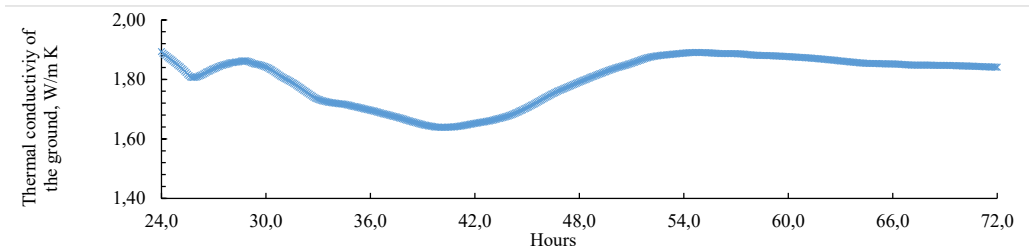
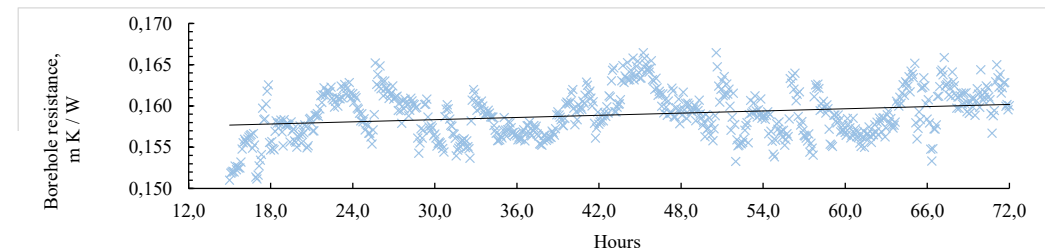
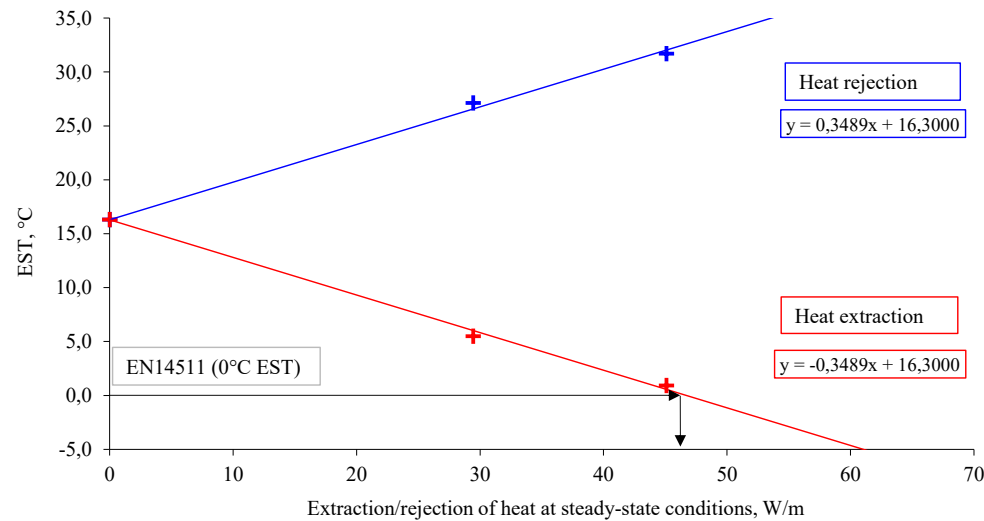
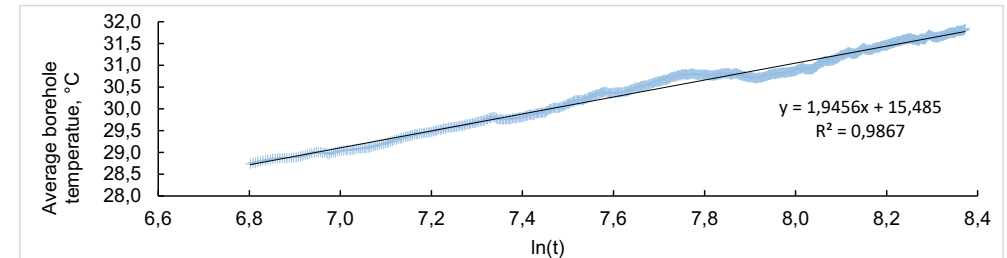
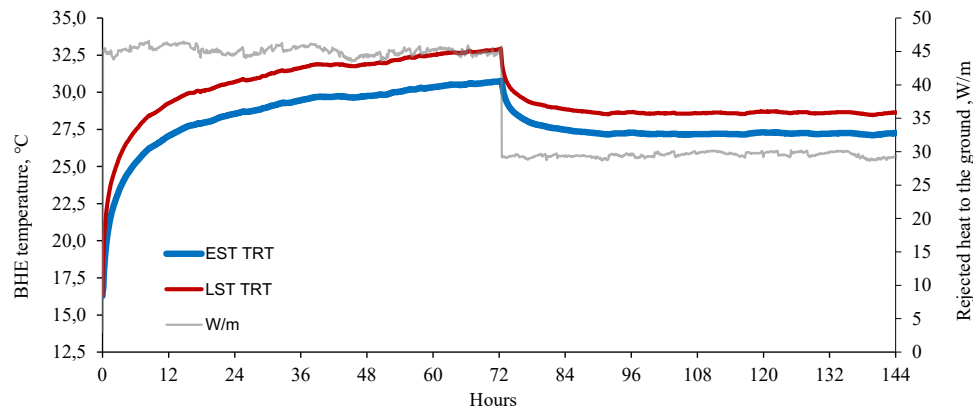
3. IMI - Institut za medicinska istraživanja i medicinu rada, Zagreb

- BHE polje – 53 BHE, 120 m dubina, ukupna duljina 6 360 m
- 1U TC45 Turbocollector SDR11
- 2 bušotinska polja
- Polje A – 6x4+2 (26 BHE)
- Polje B – 13x2+1 (27 BHE)



3. IMI - Institut za medicinska istraživanja i medicinu rada, Zagreb

- Rezultati TRT - $\lambda = 1,84 \text{ W/m K}$

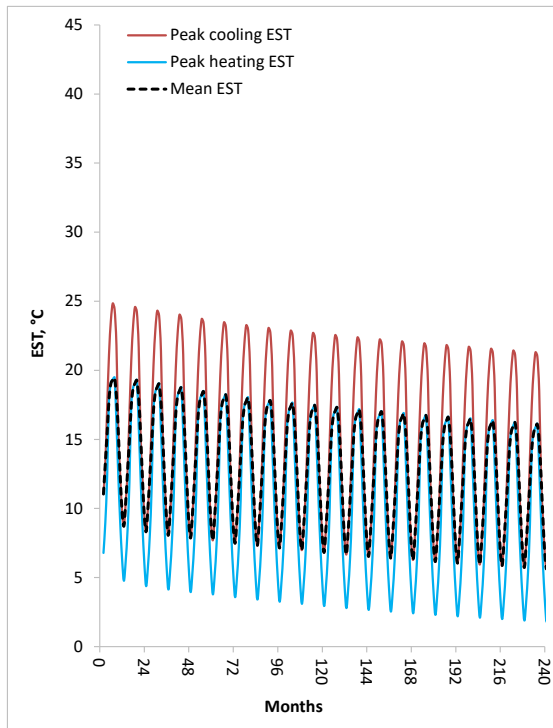


3. IMI - Institut za medicinska istraživanja i medicinu rada, Zagreb

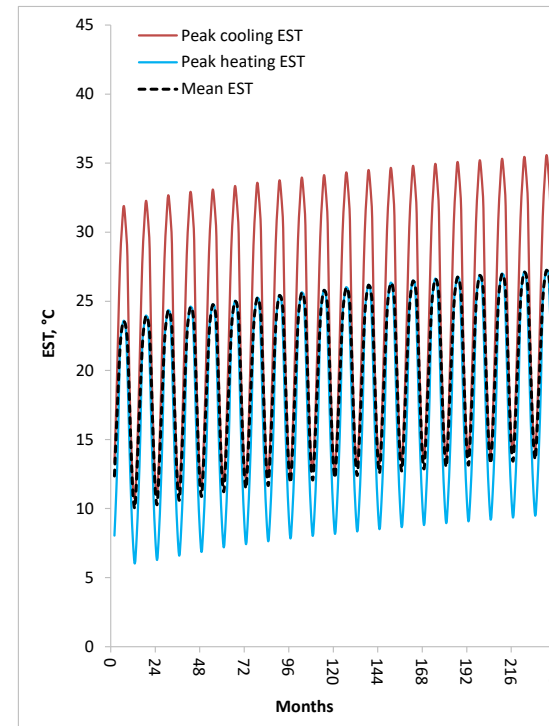
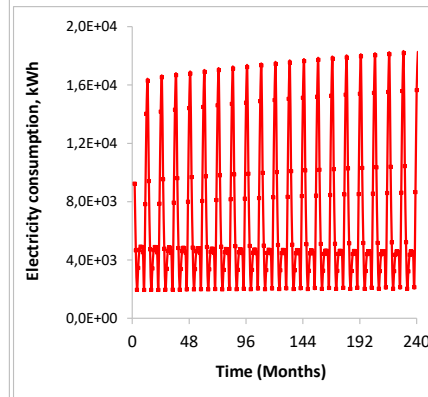
- Godišnja energija potrebna za grijanje i hlađenje - stalna promjena temperature stijene u funkciji proteklog vremena
- Mogućnost korištenja BHE polja kao BTES sustav

V1 – BTES – 300 m² kolektori

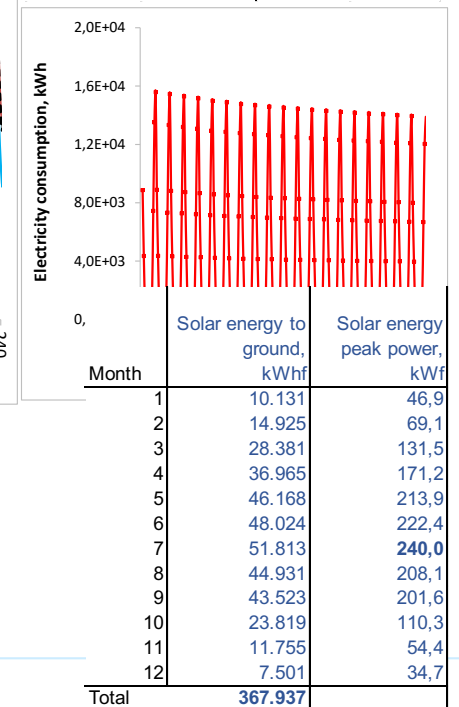
V0 – bez BTES



Tot. Heating (kWh)	Tot. Cooling (kWh)	Peak Ht (kW)	Peak Cl (kW)
105.380	0	371	0
64.570	0	339	0
34.890	0	287	0
9.662	6.065	187	82
1.500	25.057	0	164
1.500	33.676	0	227
1.500	35.112	0	266
1.500	34.793	0	243
10.775	24.898	123	182
15.598	0	196	0
57.150	0	271	0
94.250	0	321	0
398.275	159.600	371,0	266,0



Tot. Heating (kWh)	Tot. Cooling (kWh)	Peak Ht (kW)	Peak Cl (kW)
105.380	10.131	371	47
64.570	14.925	339	69
34.890	28.381	287	131
9.662	43.030	187	253
1.500	71.225	0	378
1.500	81.700	0	450
1.500	86.925	0	506
1.500	79.723	0	451
10.775	68.421	123	383
15.598	23.819	196	110
57.150	11.755	271	54
94.250	7.501	321	35
398.275	527.537	371,0	506,0

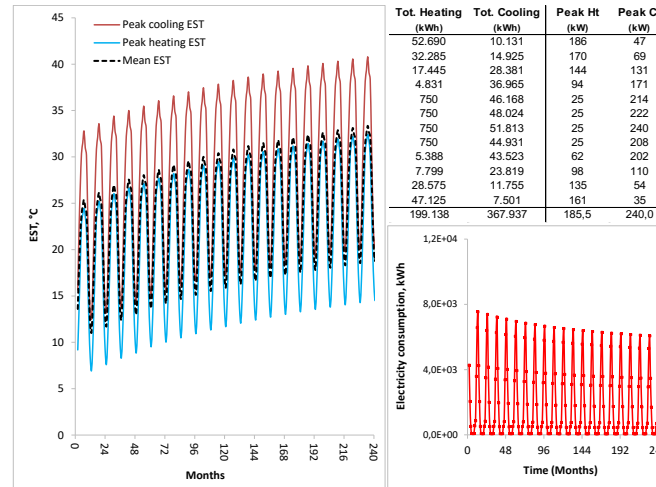
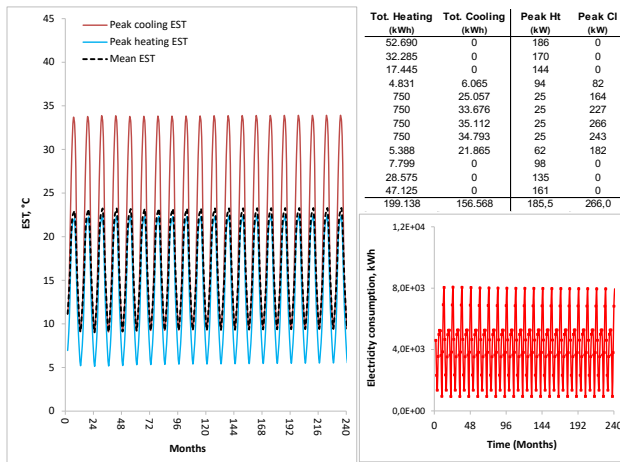


- Mogućnost korištenja BHE polja kao BTES sustav

V2 – BTES – 300 m² kolektori

A26 – ½ grijanje + cjelokupno hlađenje

B27 – ½ grijanje + solar cijele godine



Month	Solar energy to ground, kWhf	Solar energy peak power, kWf
1	10.131	46,9
2	14.925	69,1
3	28.381	131,5
4	36.965	171,2
5	46.168	213,9
6	48.024	222,4
7	51.813	240,0
8	44.931	208,1
9	43.523	201,6
10	23.819	110,3
11	11.755	54,4
12	7.501	34,7
Total	367.937	

BTES – viša učinkovitost DT zimi uz pohranu toplinske energije

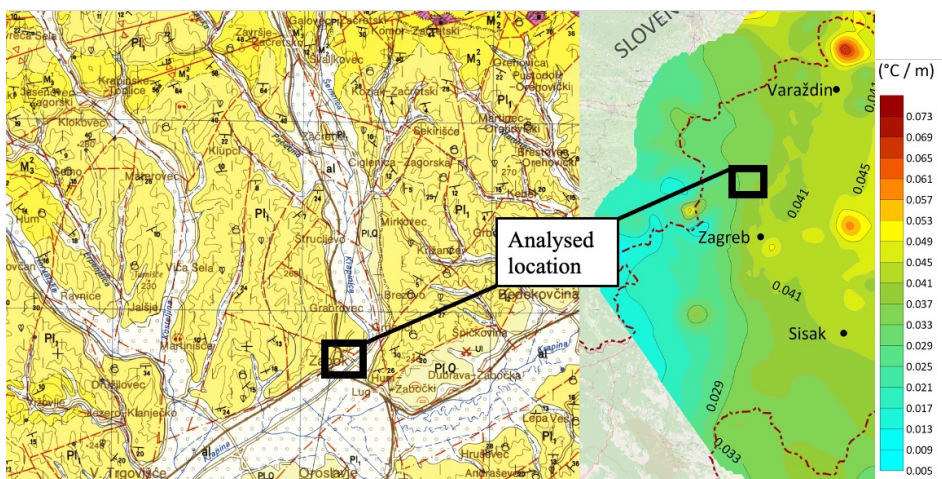
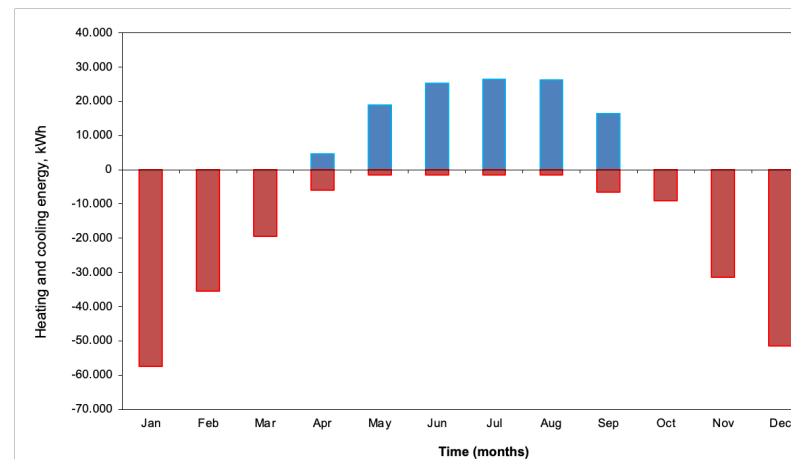
Sezona hlađenja?

Utjecaj klimatskih parametara

BTES Variant	Electricity consumption of heat pumps over 20 years, MWh
V0 initial design heating+cooling NO BTES	1603
V1 solar BTES whole field	1006
V2 A26 1/2 heating+ 1/1 cooling	1003
V2 solar BTES B27 1/2 heating + solar storage	456
V2 combined solar BTES	1459

4. re-GENERATOR – Centar urbane kulture, Zabok

- Zapuštена tvornička hala tvornice “ZIVT” - pretvorena u moderan centar urbane kulture
- 24x130m BHE 1U D45
- Mreža bušotina: 8x3 (7 m udaljenost)
- Energetske potrebe :
 - 223 MWh grijanje
 - 118 MWh hlađenje
- Vršna potrošnja:
 - 200 kW grijanje
 - 195 kW hlađenje
- TRT - $\lambda = 1,65 \text{ W/m K}$



4. re-GENERATOR – Centar urbane kulture, Zabok

- Za dubine >150 m – posebna pozornost kod projektiranja - hidrauličko balansiranje i optimizacija toplinskog otpora bušotine
- Za dublje BHE - protok prilagođen za održavanje ΔT na maksimalno 5°C u vršnim uvjetima – pad tlaka – cirkulacijska pumpa veće snage – smanjenje SCOP-a
- Modeliranje - do 300 m – 2U D40; 1U D45; 1U D50

Propylene glycol vol. Concentration, %	15,0	Depth, m	Re	pD, bar	$\Delta T, ^\circ C$	Extraction, kW	Flow, l/s both pipes	Flow, l/s per pipe
Pipe sdr11	2U D40/32,7 mm	100	2360	0,083	3,3	5,2	0,400	0,200
Specific heat, kJ/kg C	3,986	150	2573	0,144	5,0	8,7	0,437	0,218
Density, kg/m ³	1019,8	200	3847	0,380	5,0	13,0	0,652	0,326
Viscosity, mPas	3,37	250	5110	0,771	5,0	17,3	0,866	0,433
Freezing point, C	-5,3	300	6973	1,427	5,0	22,2	1,114	0,557

Propylene glycol vol. Concentration, %	20,0	Depth, m	Re	pD, bar	$\Delta T, ^\circ C$	Extraction, kW	Flow, l/s both pipes	Flow, l/s per pipe
Pipe sdr11	2U D40/32,7 mm	100	2367	0,120	2,8	5,2	0,480	0,240
Specific heat, kJ/kg C	3,929	150	2367	0,180	4,6	8,7	0,480	0,240
Density, kg/m ³	1025,8	200	3264	0,414	5,0	13,0	0,662	0,331
Viscosity, mPas	4,05	250	4330	0,836	5,0	17,3	0,878	0,439
Freezing point, C	-7,3	300	5972	1,546	5,0	22,2	1,130	0,565

Propylene glycol vol. Concentration, %	25,0	Depth, m	Re	pD, bar	$\Delta T, ^\circ C$	Extraction, kW	Flow, l/s both pipes	Flow, l/s per pipe
Pipe sdr11	2U D40/32,7 mm	100	2345	0,222	2,1	5,2	0,650	0,325
Specific heat, kJ/kg C	3,861	150	2345	0,342	3,5	8,7	0,650	0,325
Density, kg/m ³	1031,0	200	2431	0,472	5,0	13,0	0,673	0,337
Viscosity, mPas	5,57	250	3225	0,951	5,0	17,3	0,894	0,447
Freezing point, C	-10,0	300	4148	1,753	5,0	22,2	1,150	0,575

Propylene glycol vol. Concentration, %	15,0	Depth, m	Re	pD, bar	$\Delta T, ^\circ C$	Extraction, kW	Flow, l/s both pipes
Pipe sdr11	1U D45/36,8 mm	100	2726	0,074	5,0	5,2	0,261
Specific heat, kJ/kg C	3,986	150	4582	0,269	5,0	8,7	0,437
Density, kg/m ³	1019,8	200	6837	0,714	5,0	13,0	0,652
Viscosity, mPas	3,37	250	9081	1,458	5,0	17,3	0,866
Freezing point, C	-5,3	300	11681	2,710	5,0	22,2	1,114

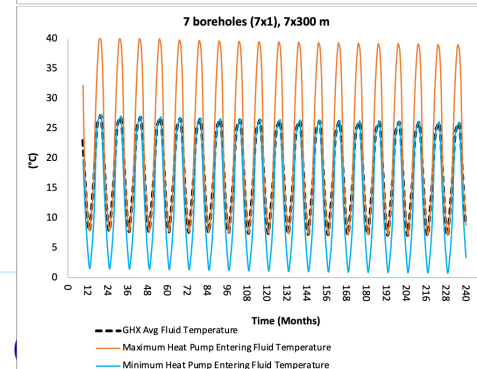
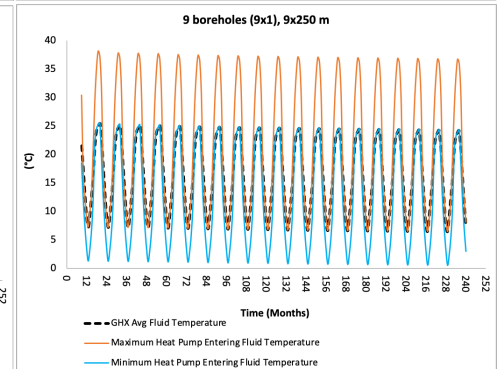
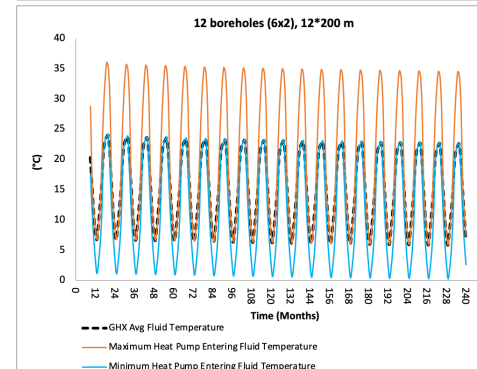
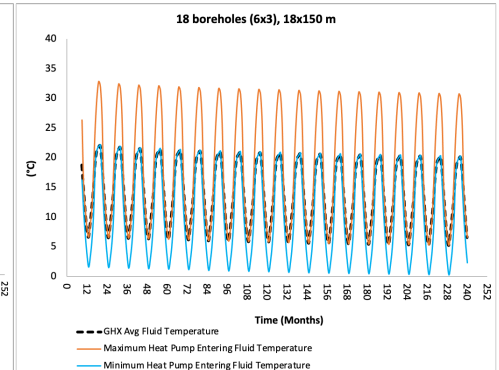
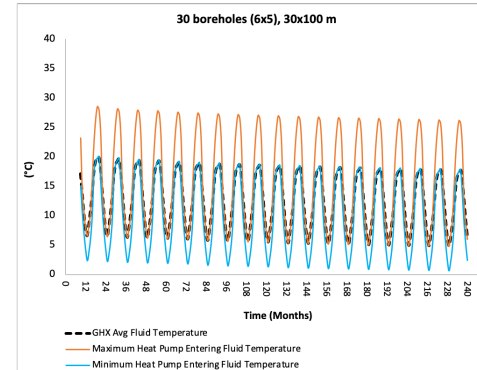
Propylene glycol vol. Concentration, %	20,0	Depth, m	Re	pD, bar	$\Delta T, ^\circ C$	Extraction, kW	Flow, l/s both pipes
Pipe sdr11	1U D45/36,8 mm	100	2322	0,082	5,0	5,2	0,265
Specific heat, kJ/kg C	3,929	150	3882	0,292	5,0	8,7	0,443
Density, kg/m ³	1025,8	200	5802	0,775	5,0	13,0	0,662
Viscosity, mPas	4,05	250	7695	1,576	5,0	17,3	0,878
Freezing point, C	-7,3	300	9903	2,928	5,0	22,2	1,130

Propylene glycol vol. Concentration, %	25,0	Depth, m	Re	pD, bar	$\Delta T, ^\circ C$	Extraction, kW	Flow, l/s both pipes
Pipe sdr11	1U D45/36,8 mm	100	2372	0,159	3,6	5,2	0,370
Specific heat, kJ/kg C	3,861	150	2891	0,333	5,0	8,7	0,451
Density, kg/m ³	1031,1	200	4314	0,877	5,0	13,0	0,673
Viscosity, mPas	5,57	250	5724	1,779	5,0	17,3	0,893
Freezing point, C	-10	300	7372	3,300	5,0	22,2	1,150

Propylene glycol vol. Concentration, %	15,0	Depth, m	Re	pD, bar	$\Delta T, ^\circ C$	Extraction, kW	Flow, l/s both pipes
Pipe sdr11	1U TC50/40,9	100	2462	0,059	5,0	5,2	0,261
Specific heat, kJ/kg C	3,9855	150	4123	0,164	5,0	8,7	0,437
Density, kg/m ³	1019,8	200	6152	0,434	5,0	13,0	0,652
Viscosity, mPas	3,37	250	8171	0,884	5,0	17,3	0,866
Freezing point, C	-5,3	300	10510	1,640	5,0	22,2	1,114

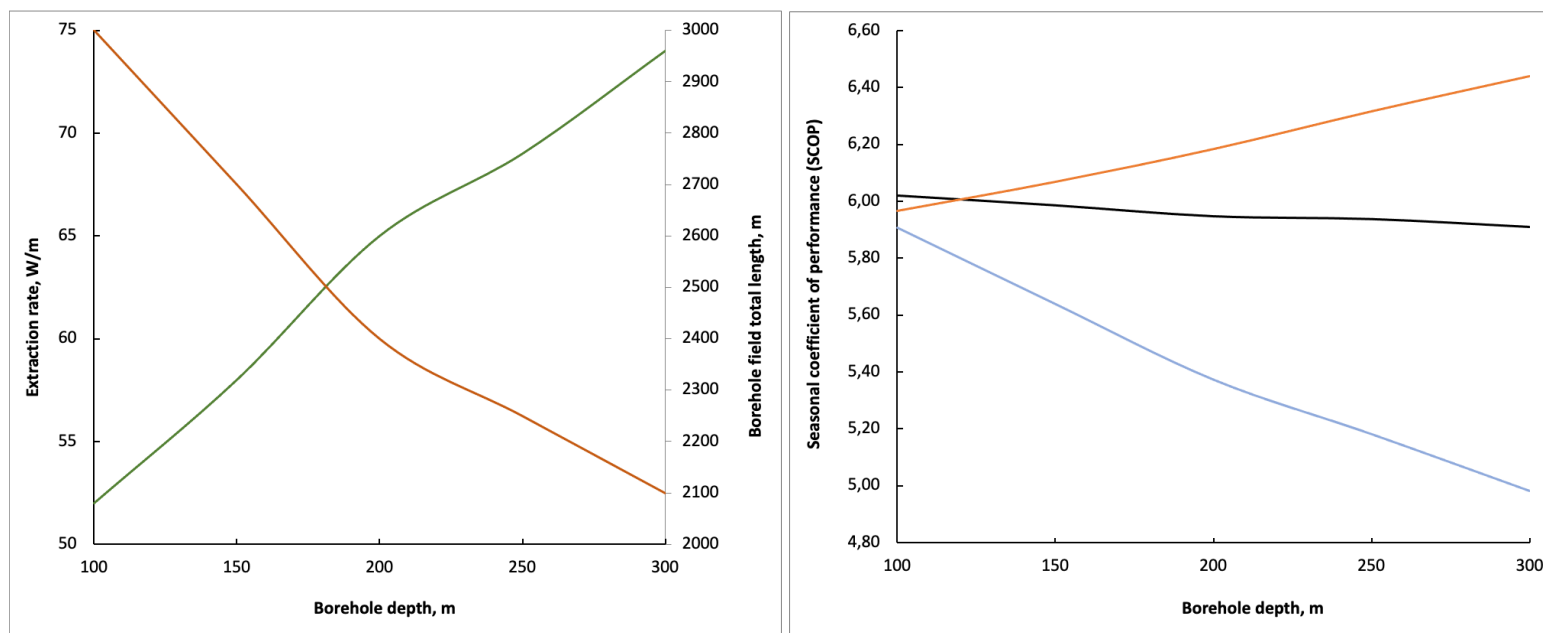
Propylene glycol vol. Concentration, %	20,0	Depth, m	Re	pD, bar	$\Delta T, ^\circ C$	Extraction, kW	Flow, l/s both pipes
Pipe sdr11	1U TC50/40,9	100	2366	0,061	4,4	5,2	0,300
Specific heat, kJ/kg C	3,929	150	3493	0,178	5,0	8,7	0,443
Density, kg/m ³	1025,8	200	5220	0,471	5,0	13,0	0,662
Viscosity, mPas	4,05	250	6876	0,945	5,0	17,3	0,872
Freezing point, C	-7,3	300	8910	1,778	5,0	22,2	1,130

Propylene glycol vol. Concentration, %	25,0	Depth, m	Re	pD, bar	$\Delta T, ^\circ C$	Extraction, kW	Flow, l/s both pipes
Pipe sdr11	1U TC50/40,9	100	2365	0,115	3,3	5,2	0,410
Specific heat, kJ/kg C	3,861	150	2601	0,203	5,0	8,7	0,451
Density, kg/m ³	1031,1	200	3882	0,533	5,0	13,0	0,673
Viscosity, mPas	5,57	250	5151	1,081	5,0	17,3	0,893
Freezing point, C	-10	300	6633	2,003	5,0	22,2	1,150



4. re-GENERATOR – Centar urbane kulture, Zabok

- Porast temperature s dubinom – porast pridobive toplinske energije, ali u isto vrijeme degradacija mogućnosti pohrane toplinske energije tijekom sezone hlađenja
- SCOP - nema kumulativnog dobitka s primjenom dublje BHE, za razliku od standardnih rješenja sa 100 m
- Tehnoekonomska analiza - povećanje troškova bušenja u odnosu na manje BHE potrebno za dublje rješenje? Pad tlaka?



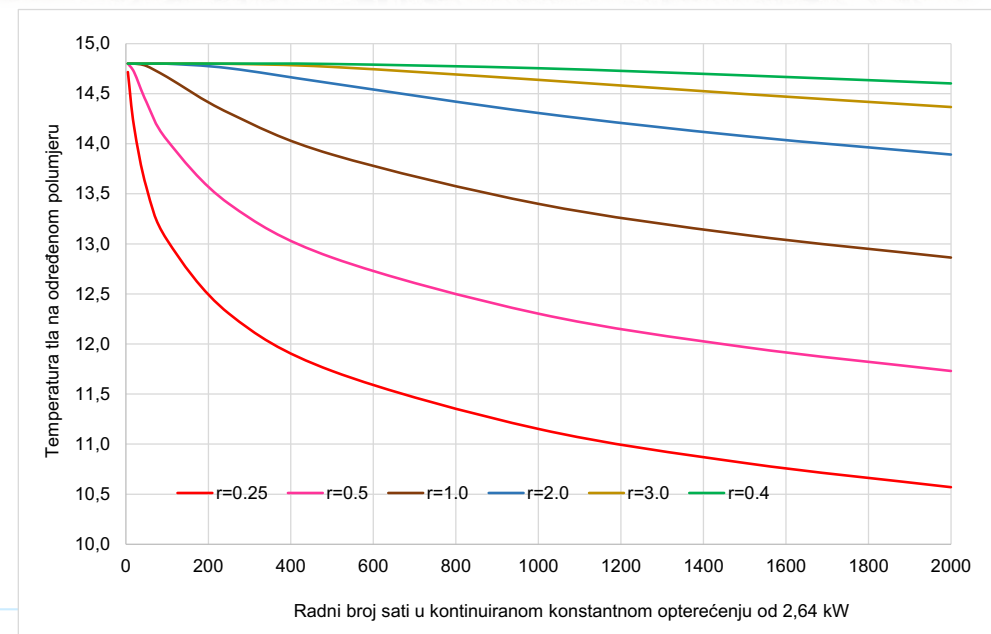
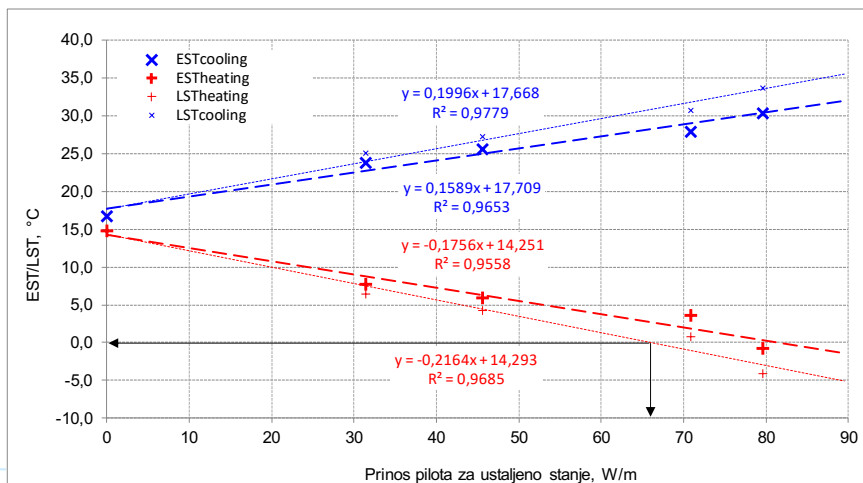
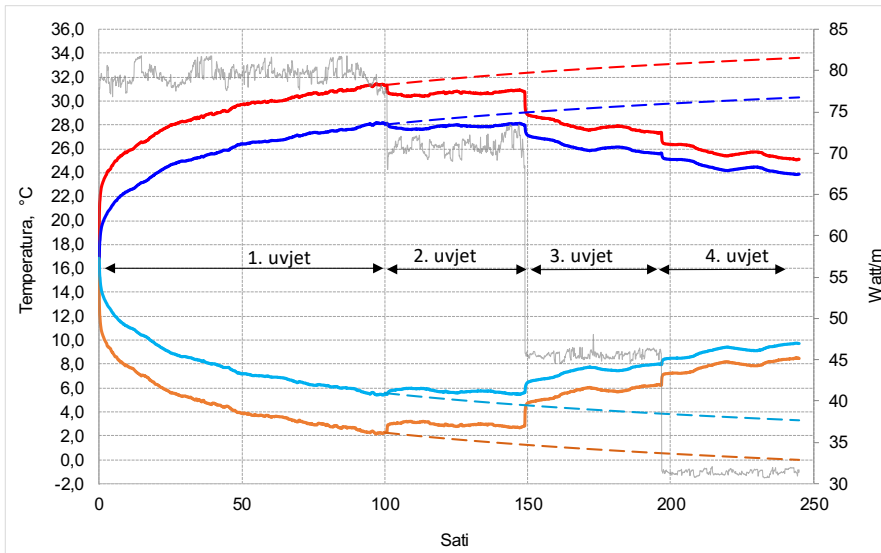
5. Designer Outlet, Zagreb

- 2017.g. - IKEA faza 2 – shopping centar Designer Outlet centar
- Konstrukcijski 13 zasebnih dilatacija (A-M)
- 260 energetskih pilota * 20m
- Paralelni bivalentni sustav – geotermalna/plin
- Potrebe: 457 kW grijanje i 477 kW hlađenje



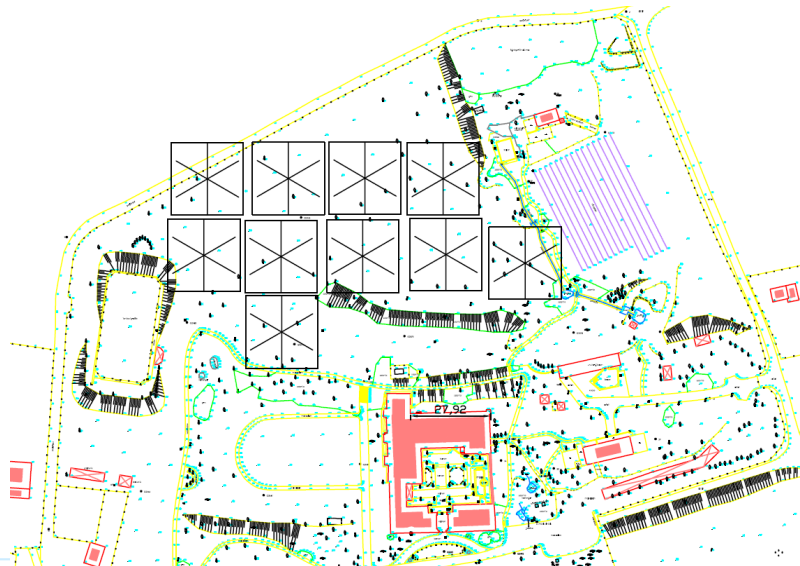
5. Designer Outlet, Zagreb

- TRT – dva serijski spojena pilota dilatacije C
- $\lambda = 2,49 \text{ W/m K}$ (40 m pilot)
- Termalna interferencija



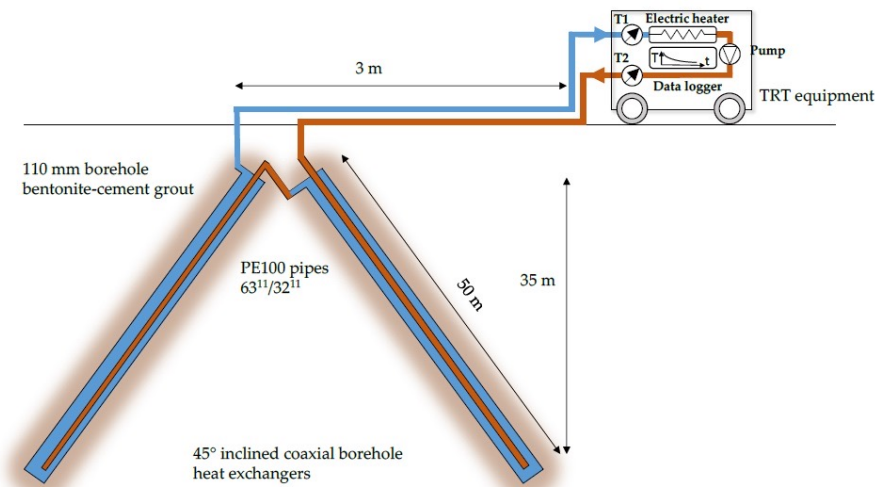
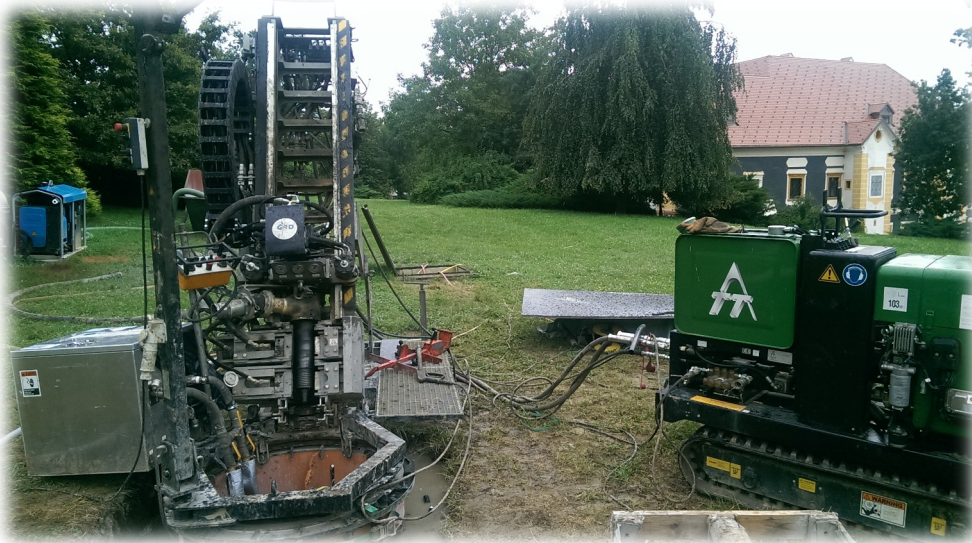
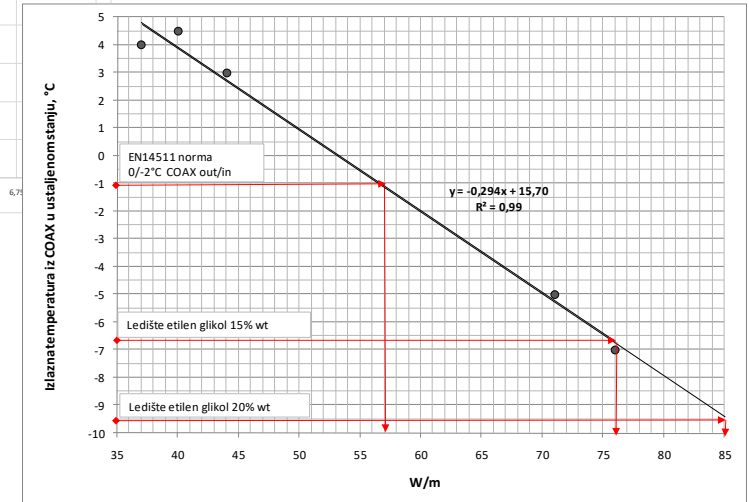
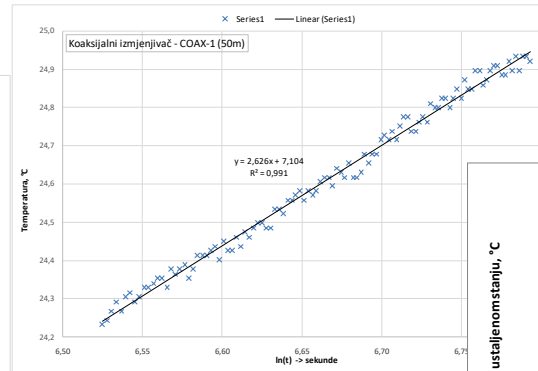
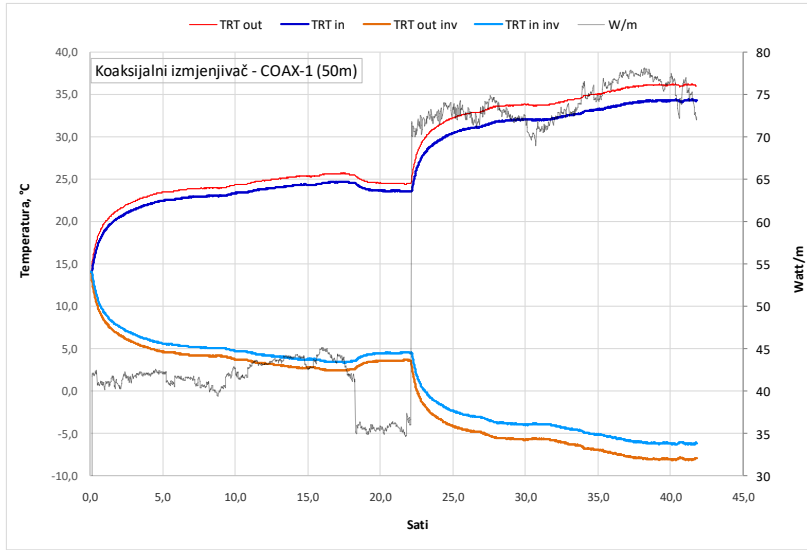
6. Dvorac Miljana, Poljana Sutlanska

- Godina prve izgradnje: 1600 g. (obitelj Ratkaj do 1800.)
- Restauracija: 2014.
- Bruto površina zgrade: 4 787 m²
- Geotermalno rješenje u strojarskom projektu 2015. – u fazi razmatranja bušotinski koaksijalni izmjenjivači
- Odrađena testna bušotina za determiniranje termogeoloških parametara tla i projektiranje geotermalnog izmjenjivača (TRT)
- 80 COAX bušotina po 50 m
- Toplinsko opterećenje 280 kW; Rashladno opterećenje 200 kW



6. Dvorac Miljana, Poljana Sutlanska

• TRT - $\lambda = 1,32 \text{ W/m K}$





Hvala na pažnji!

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