Geothermal Energy for Energy Security in Bulgaria

Geothermal energy: utilization and ongoing initiatives

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Sofia

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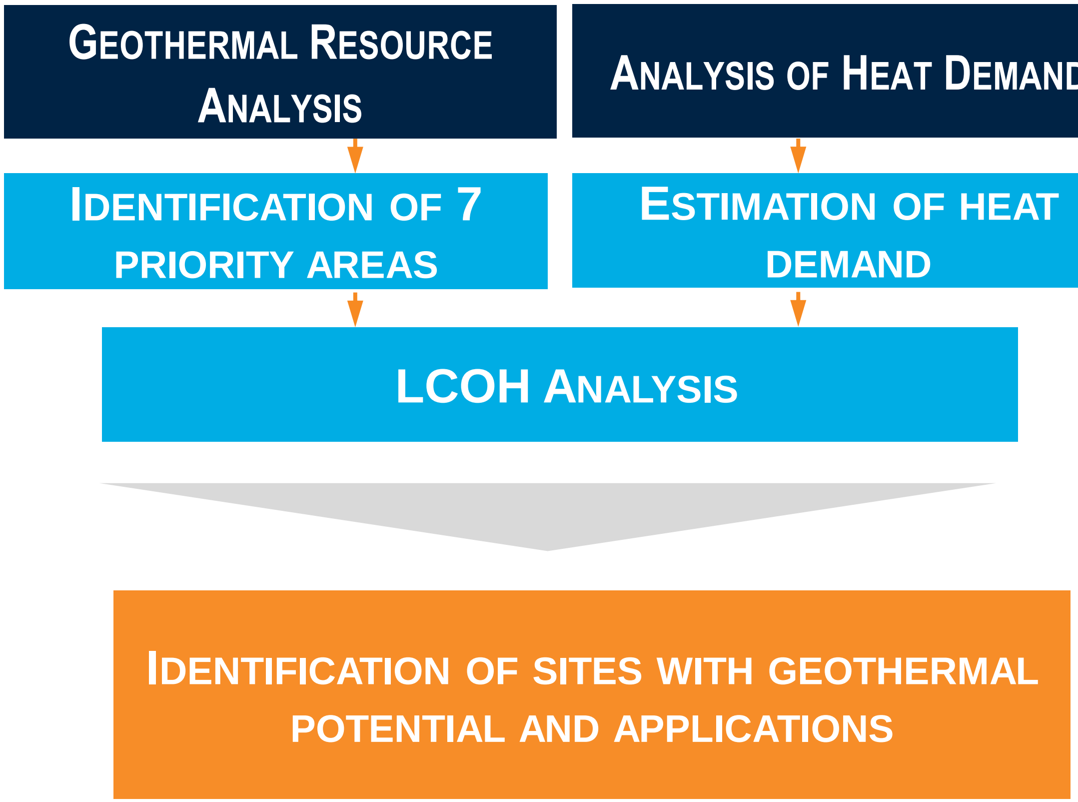
Scope of the presentation

I	IDENTIFICATION OF SITES WITH GEOTHERMAL POTENTIAL IN BULGARIA
II	DEVELOPMENT OF GEOTHERMAL HEAT PUMPS SECTOR IN BULGARIA

I IDENTIFICATION OF SITES WITH GEOTHERMAL POTENTIAL

II DEVELOPMENT OF GEOTHERMAL HEAT PUMPS SECTOR

Methodology for the identification of sites with geothermal potential

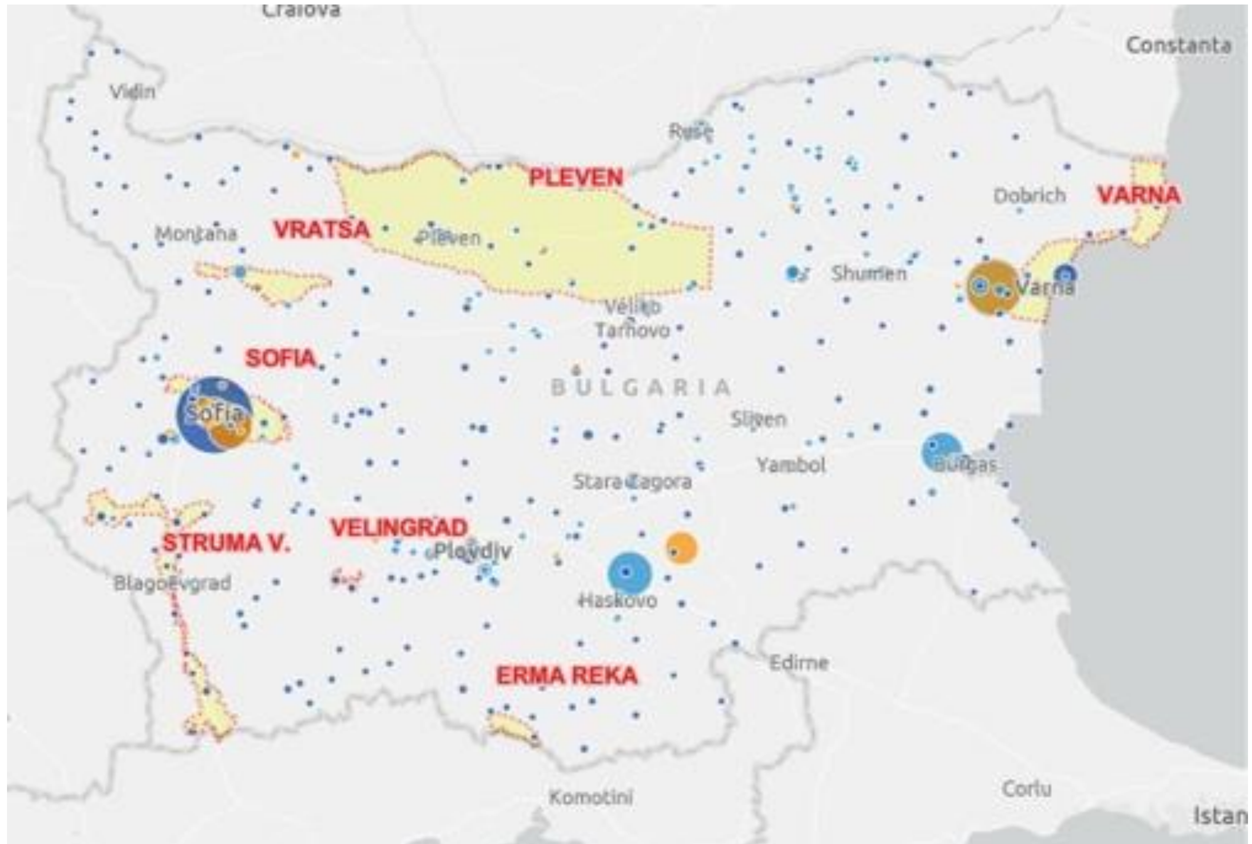


Data consolidation tool

Heat Demand Map

Geothermal Resources

Consolidated Map: Heat Demand and Geothermal Resources



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7 priority areas with potential resources suitable for direct use of heat

Key Findings of Resources Assessment

- **7 proposed priority areas**, more likely to contain resources to kickstart the geothermal development in Bulgaria:
  - North Bulgaria: **Pleven, Varna, Vratsa** (Malm-Valanginian aquifer only).
  - Central Bulgaria: **Sofia Basin.**
  - Southern Bulgaria: **Struma Valley** (including Sapareva Banya and Kyustendil), **Velingrad**, and **Erma Reka**.
- Confirmed geothermal resources in these areas with maximum measured temperatures in the 70-110° C range – **suitable for direct use of heat.**

Proposed Priority Areas

Geothermal Area	*Pleven*	*Varna*	*Vratsa*	*Sofia*	*Velingrad*	*Struma Valley*	*Erma Reka*
Temperature range (°C). Measured in existing wells and thermal springs	30-110	30-70	50-90	30-80	32-97	30-98	70-90
Water salinity (TDS mg/l)	1000-30000	1000-5000	5000-15000	2000-5000	200-850	300-4500	100-1700
Resource depth (m) As known from existing boreholes	800-2300	400-1400	1100-2100	300-700	300-800	150-700	500-900
Thermal power potentially extractable (MWt) Minimum estimate, based on measured resource data	622	217	62	48	27	78	15

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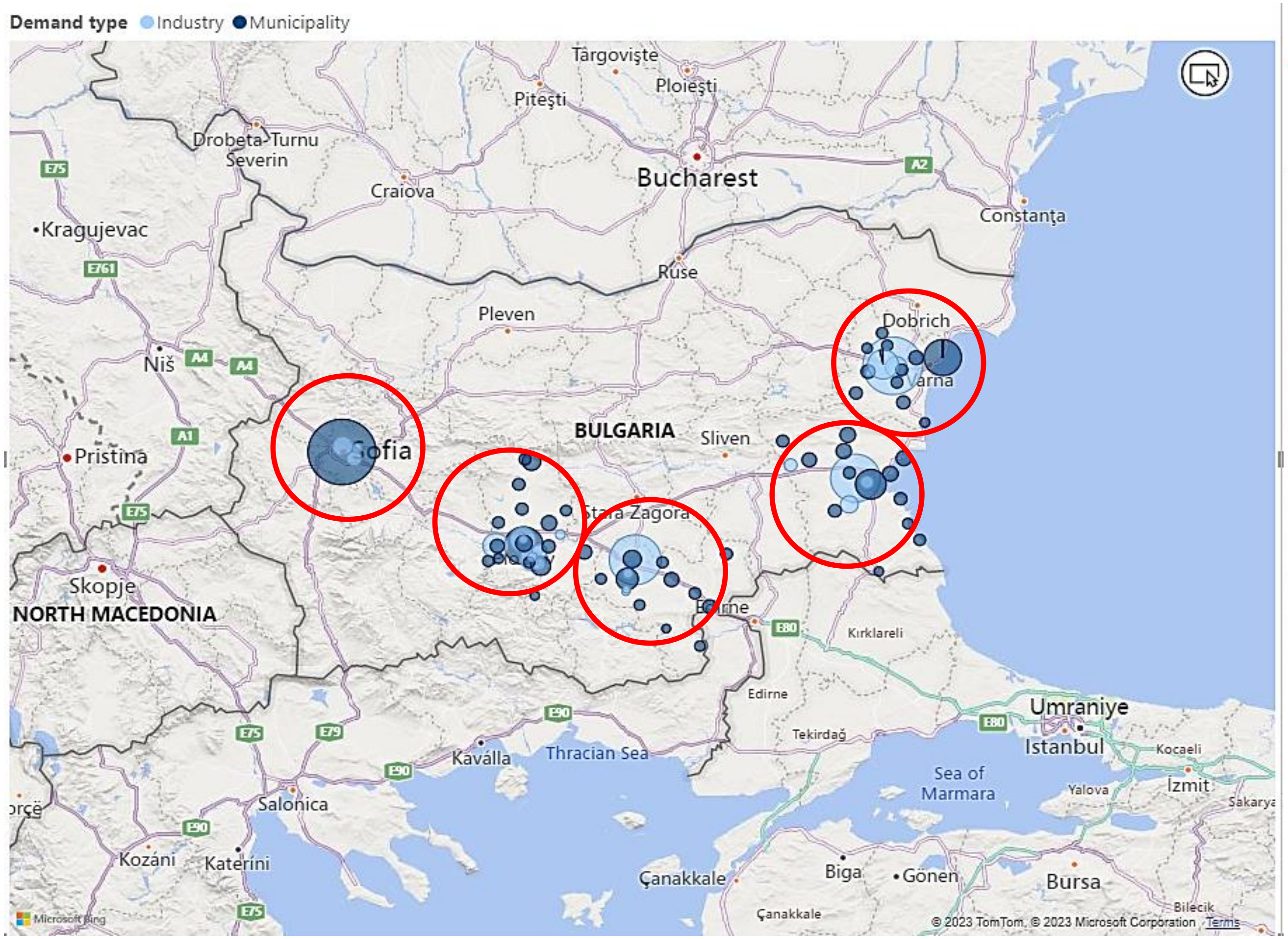
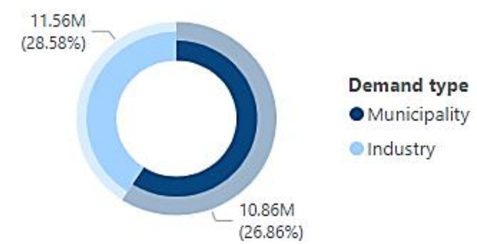
Heat demand in Bulgaria is concentrated around five regions: Sofia, Varna, Burgas, Plovdiv, and Haskovo. These regions account for 26% of the total residential demand and 28% of the total industrial demand.

HEAT DEMAND (2022) BY REGION AND INDUSTRY TYPE



Region	Industry	Municipality	Total
Varna	4524083	1597685	6121768
Sofia-city	308076	4747788	5055864
Burgas	2571408	1403925	3975333
Plovdiv	1562257	2341813	3904070
Haskovo	2592405	769233	3361638
Veliko Tarnovo	847229	756603	1603832
Targovishte	1049831	356737	1406568
Sofia	374346	844031	1218377
Stara Zagora	50751	1082260	1133011
Blagoevgrad	10779	1068570	1079349
Shumen	493007	554856	1047863
Pleven	225530	817098	1042628
Vratsa	452479	552061	1004540
Beli izvor	452339		452339
Vratsa		223833	223833
Byala Slatina		71792	71792
Kozloduy		65762	65762
Mezdra	140	63155	63295
Oryahovo		30834	30834
Krivodol		27378	27378
Miziya		20447	20447
Roman		17544	17544
Borovan		17421	17421
Hayredin		13895	13895
Pazardzhik	162469	838837	1001306
Ruse	160612	703168	863780
Razgrad	473257	374929	848186
Pernik	353778	414382	768160

Heat Demand MWht (2022) by Demand type



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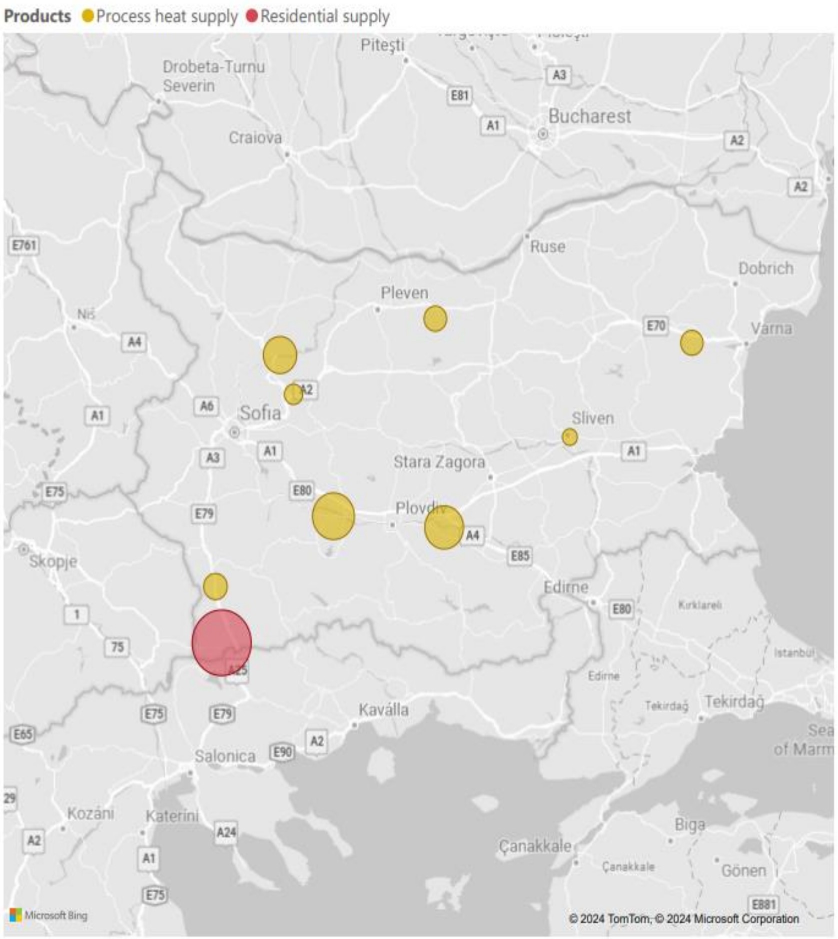
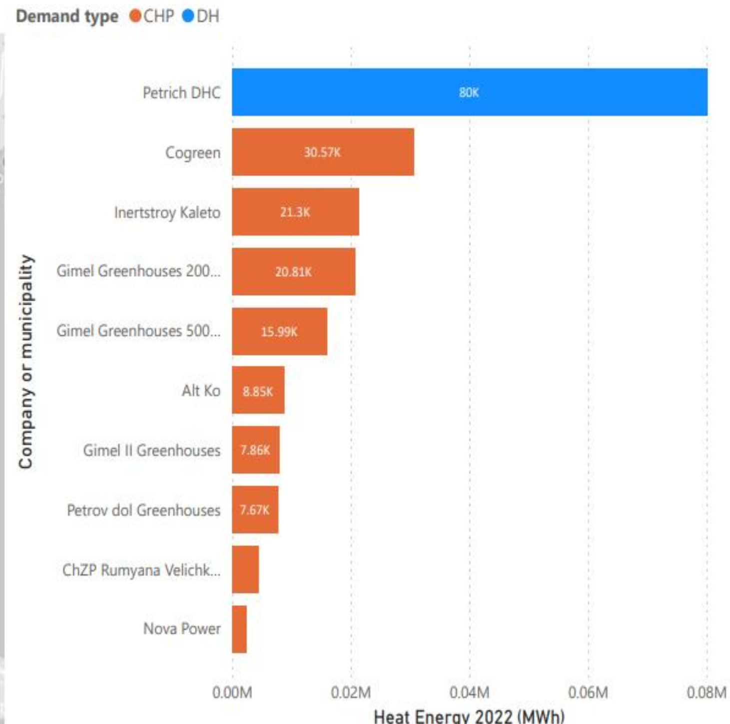
Sofia-city represents the largest heat demand residential area, accounting for approximately 20% of Bulgaria's total heat demand. The ten largest heat consumers account for over 45% of total heat demand.

KEY FINDING	DESCRIPTION
Sofia is the biggest residential heat demand area	▪ **Sofia-city represents, by far, the biggest residential heat demand area** (~20% total heat demand in Bulgaria), and the district heating of Sofia the largest heat generation company of its kind in Bulgaria, with a share of 61% of the national DH heat generation.
High concentration of the heat demand	▪ 3 large industrial players aggregate 50% of the total industrial heat demand in Bulgaria: **Solvay Sodi, Neochim** and **Lukoil Neftochim refinery**. ▪ The **10 largest** heat consumers account for **>45%** of the total heating demand in 2022.
Plovdiv, Varna and Burgas are important heat demand centers	▪ The cities **of Plovdiv, Varna and Burgas** are the remaining entities with estimated heat demand above 1 million MWht per year.
Five regions account for a quarter of heat demand in Bulgaria	▪ The regions of **Sofia, Varna, Burgas, Plovdiv, and Haskovo**, accounting for 26% of the total residential demand and 28% of the total industrial demand, represent the 5 zones with larger heat demand in Bulgaria.

Greenhouses, currently supplied mainly by CHP units, also have potential for direct usage of geothermal energy. There are already existing greenhouses in geothermal regions of Struma Valley, Vratsa, and Pleven.

HEAT ENERGY – GREENHOUSES BULGARIA (2022)



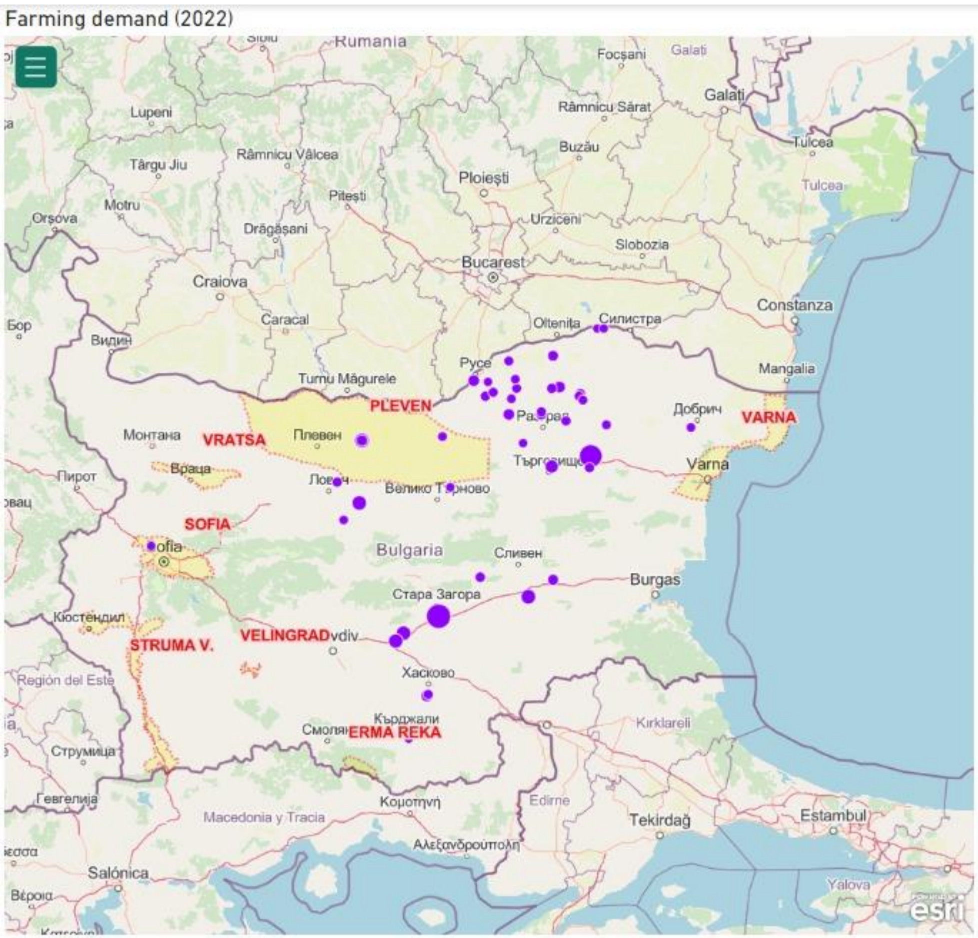


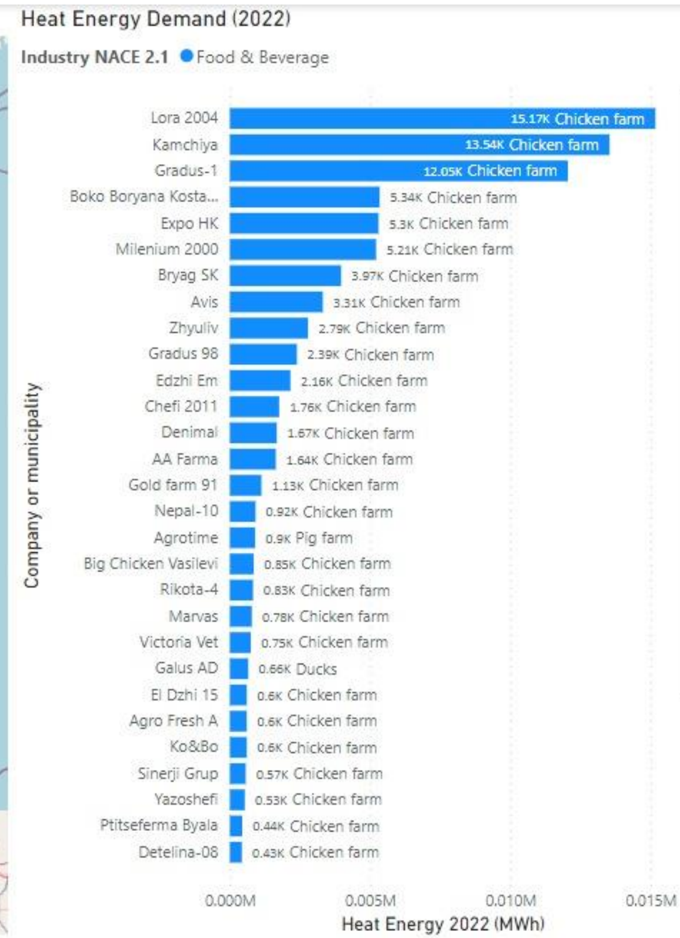
Heat Energy Demand (2022) - Greenhouse Industry (MWh)

199,700 MWHT

Poultry and pig farms have good prospects for geothermal energy, with farming accounting for 88,600 MWh/year.

HEAT DEMAND (2022) OF AGRICULTURAL SECTOR





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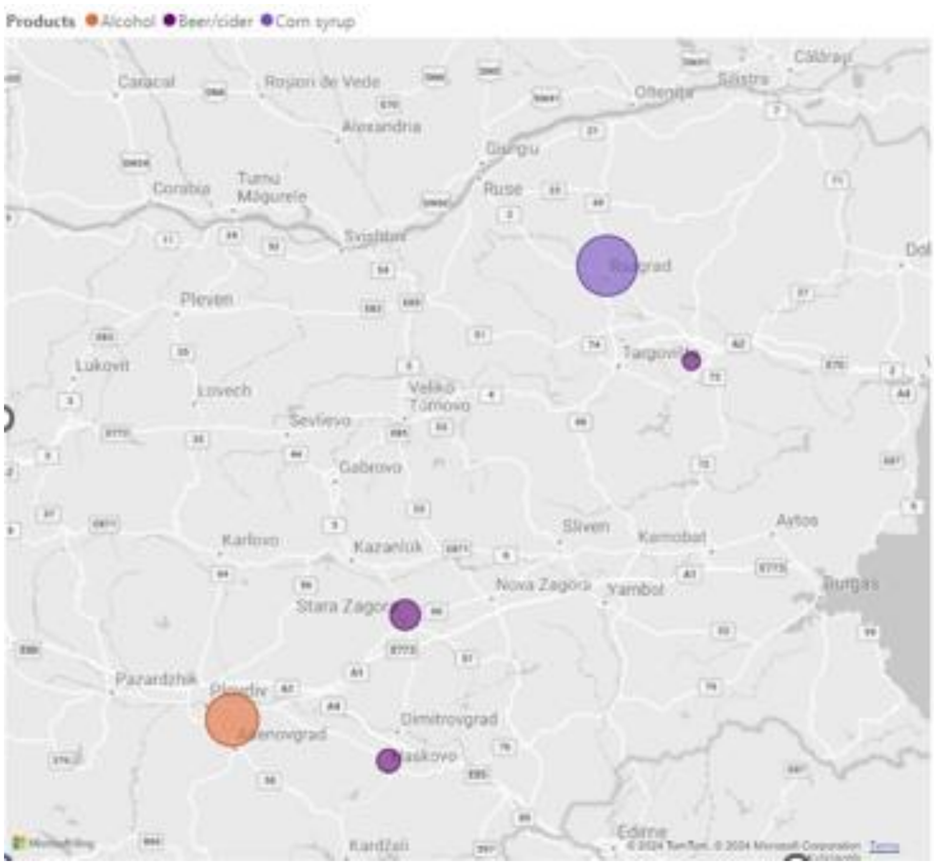
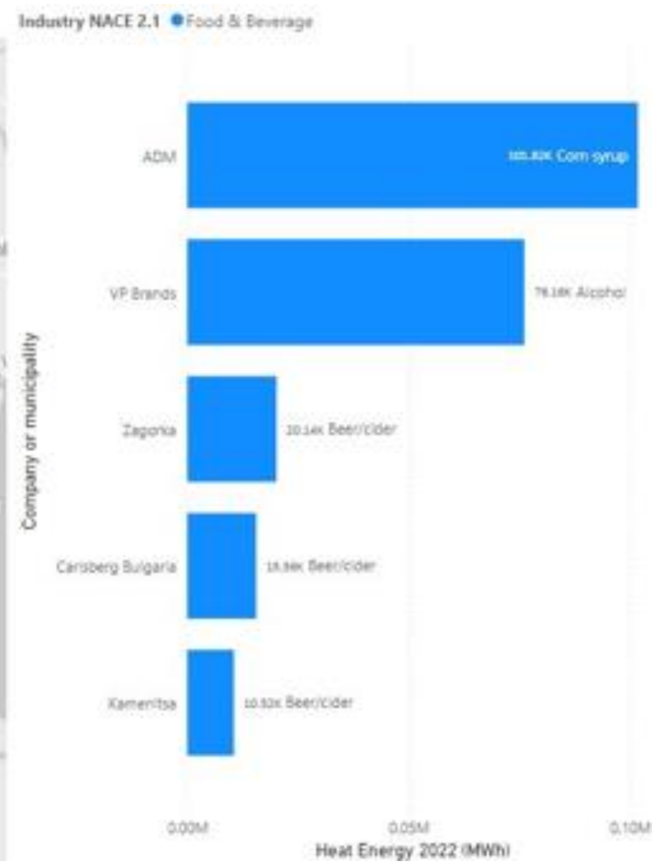
Food and Beverages most promising, as processes require lower temperatures 319.000 MWht/y
Few matches with identified geothermal areas, however.

FOOD & BEVERAGE FACILITIES





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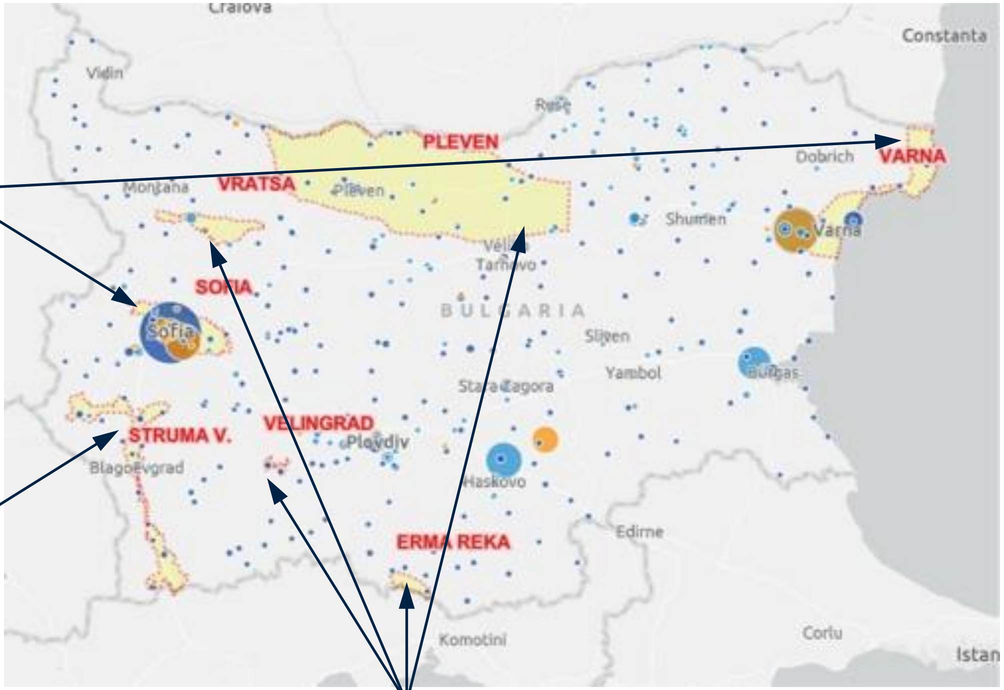
Summary of findings: Matching geothermal resources and heat demand

Sofia and Varna: concentrate important heat demand coupled with existing infrastructures (production, network) and low-risk geothermal potential, as well as coal-fired facilities aimed at producing heat and transitioning to carbon-neutral fuel or being phased out in the medium term.

In the **Struma Valley**, existing greenhouse businesses could provide opportunities for switching to, and/or expansion, of geothermal based greenhouses.



In the other areas identified - **Pleven, Vratsa, Velingrad, and Erma Reka** - heat demand is more dispersed and limited. In addition, in Pleven and Vratsa, the hotter geothermal resource is located at depths exceeding 2,000 m, that may challenge the financial viability of small geothermal developments.

LCOH calculation tool: Methodology

Application of Tool in Geothermal Areas: Example of DH in Sofia

Flow rate

[l/s]	[t/h]	41	45	50	55	60	65	70	75	80	85	90	95	100	105	110
85	306	1,152	5,762	11,524	17,285	23,047	28,809	34,571	40,333	46,095	51,856	57,618	63,380	69,142	74,904	80,666
80	288	1,085	5,423	10,846	16,269	21,692	27,114	32,537	37,960	43,383	48,806	54,229	59,652	65,075	70,498	75,921
75	270	1,017	5,084	10,168	15,252	20,336	25,420	30,504	35,588	40,672	45,756	50,840	55,924	61,008	66,092	71,176
70	252	949	4,745	9,490	14,235	18,980	23,725	28,470	33,215	37,960	42,705	47,450	52,195	56,940	61,685	66,430
65	234	881	4,406	8,812	13,218	17,624	22,031	26,437	30,843	35,249	39,655	44,061	48,467	52,873	57,279	61,685
60	216	813	4,067	8,134	12,202	16,269	20,336	24,403	28,470	32,537	36,605	40,672	44,739	48,806	52,873	56,940
55	198	746	3,728	7,456	11,185	14,913	18,641	22,369	26,098	29,826	33,554	37,282	41,011	44,739	48,467	52,195
50	180	678	3,389	6,779	10,168	13,557	16,947	20,336	23,725	27,114	30,504	33,893	37,282	40,672	44,061	47,450
45	162	610	3,050	6,101	9,151	12,202	15,252	18,302	21,353	24,403	27,453	30,504	33,554	36,605	39,655	42,705
40	144	542	2,711	5,423	8,134	10,846	13,557	16,269	18,980	21,692	24,403	27,114	29,826	32,537	35,249	37,960
35	126	475	2,373	4,745	7,118	9,490	11,863	14,235	16,608	18,980	21,353	23,725	26,098	28,470	30,843	33,215
30	108	407	2,034	4,067	6,101	8,134	10,168	12,202	14,235	16,269	18,302	20,336	22,369	24,403	26,437	28,470
25	90	339	1,695	3,389	5,084	6,779	8,473	10,168	11,863	13,557	15,252	16,947	18,641	20,336	22,031	23,725
20	72	271	1,356	2,711	4,067	5,423	6,779	8,134	9,490	10,846	12,202	13,557	14,913	16,269	17,624	18,980
15	54	203	1,017	2,034	3,050	4,067	5,084	6,101	7,118	8,134	9,151	10,168	11,185	12,202	13,218	14,235

[°C] Production temperature

Heat Production

MWht	kWt	450	600	750	900	1,050	1,200	1,350	1,500	1,650	1,800	1,950	2,100	2,250	2,400	2,550
66,400	18,500	28.9	30.8	32.9	35.0	37.2	39.5	41.9	44.3	46.9	49.5	52.1	54.9	57.7	60.6	63.6
48,500	13,500	34.1	36.8	39.6	42.5	45.6	48.7	51.9	55.3	58.7	62.3	66.0	69.7	73.6	77.6	81.7
40,700	11,400	37.8	41.0	44.4	47.9	51.5	55.2	59.1	63.1	67.2	71.4	75.8	80.3	84.9	89.7	94.5
36,600	10,200	40.4	44.0	47.7	51.6	55.6	59.8	64.1	68.5	73.1	77.8	82.6	87.6	92.8	98.1	103.5
33,600	9,400	42.7	46.6	50.7	54.9	59.3	63.8	68.5	73.3	78.3	83.4	88.7	94.2	99.8	105.5	111.4
29,800	8,300	46.3	50.7	55.3	60.0	64.9	70.0	75.3	80.8	86.4	92.2	98.2	104.3	110.6	117.1	123.7
27,100	7,600	49.4	54.3	59.3	64.5	70.0	75.6	81.4	87.4	93.5	99.9	106.5	113.2	120.2	127.3	134.6
23,725	6,600	54.4	59.9	65.7	71.6	77.8	84.2	90.9	97.7	104.8	112.0	119.5	127.2	135.2	143.3	151.7
20,300	5,700	61.1	67.5	74.3	81.2	88.5	96.0	103.7	111.7	119.9	128.5	137.2	146.2	155.5	165.0	174.8
18,300	5,100	66.1	73.3	80.8	88.5	96.5	104.8	113.4	122.3	131.5	140.9	150.6	160.6	170.9	181.4	192.3
15,300	4,300	76.2	84.8	93.7	103.0	112.6	122.5	132.8	143.4	154.3	165.6	177.3	189.2	201.5	214.1	227.1
13,600	3,800	83.9	93.6	103.6	114.0	124.8	136.0	147.6	159.5	171.8	184.5	197.6	211.0	224.9	239.1	253.7
9,500	2,700	113.8	127.6	142.0	156.9	172.4	188.4	204.9	222.0	239.6	257.8	276.5	295.8	315.6	335.9	356.8
8,100	2,300	130.9	147.1	164.0	181.5	199.6	218.4	237.8	257.8	278.5	299.8	321.8	344.3	367.6	391.4	415.9
6,800	1,900	153.1	172.5	192.5	213.4	235.0	257.3	280.4	304.3	328.9	354.3	380.5	407.4	435.0	463.5	492.6

[m] Drilling depth

LCOH ALTERNATIVE SOURCES (EUR/MWh)

	Natural Gas	Electricity	Hard Coal
Base:	86.36	157.90	116.12
Adjusted:	110.99	181.47	181.84

Step 1

Assessment of heat generation potential based on the flow rate and temperature.

Step 2

Assessment of the LCOH range based on possible heat generation as well as technical, and economic parameters

Step 3

Comparison with potential alternatives

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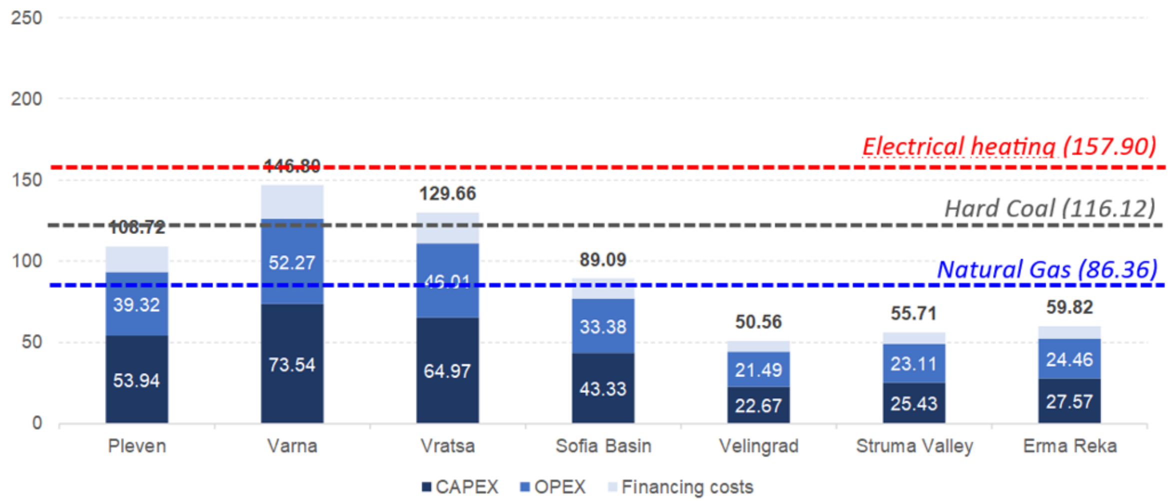
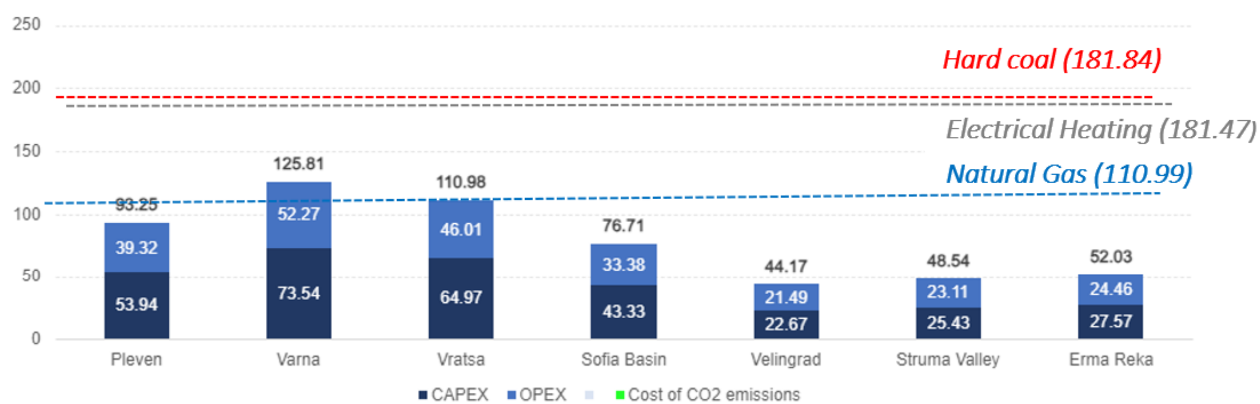
LCOH calculation tool: Geothermal energy can be competitive when compared with alternative technologies-example: 3600 hours/year
=> LCOH is competitive in all cases for industrial applications- 7000 hours/yr

LCOH for project cases in the selected geothermal areas (3,600 op. hours/year)- financial



LCOH for project cases in the selected geothermal areas (3,600 op. hours/year)- economic



Development of online LCOH calculation tool

An online tool for geothermal project developers, allowing calculation of LCOH and comparison with alternative technologies (coal, natural gas etc.) in order to inform investment decisions.

The online tool will calculate LCOH based on assumptions and input data to be provided by the project developer.

INPUT DATA	▪ Type of application ▪ Heat consumption/generation ▪ Capacity ▪ Operating hours ▪ Location
OUTPUT DATA	▪ CAPEX ▪ OPEX ▪ LCOH geothermal ▪ LCOH of alternative technology

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I	IDENTIFICATION OF SITES WITH GEOTHERMAL POTENTIAL
II	DEVELOPMENT OF GEOTHERMAL HEAT PUMPS SECTOR

Geothermal Heat Pumps: Focus on Industry and Buildings

I Approach

Methodology

Analysis of GHP for Industry

↓

Identification of industrial sectors with the highest potential to implement GHP

Analysis of GHP for Buildings

↓

Identification of types of buildings with the highest potential to implement GHP

↓

Calculation of LCOH

↓

Sensitivity analysis & calibration to determine the support levels

↓

Estimation of potential cost and benefits for Industry

Estimation of potential cost and benefits for the Building sector

↓

Recommendations related to possible supporting schemes

Contents of the Analysis

- ✓ Overview of the **key technologies**
- ✓ Identified **industrial sectors with the highest potential** for implementing GHP and estimated potential costs and benefits.
- ✓ **Building sector sub-segments with the highest potential** and estimated potential costs and benefits.
- ✓ **Sensitivity analysis tool** that allows for further calibration depending on the requirements – LCOH, CAPEX, OPEX, support levels
- ✓ **Estimates of the total technical potential** (capacity and investments) and impact (energy and GHG savings)
- ✓ Comparing the potential net benefits related to industry and buildings enabled the preparation of **recommendations for support schemes**
- ✓ **Support schemes good practice examples** (household support schemes in Europe)
- ✓ **Recommendations** for scaling up investments

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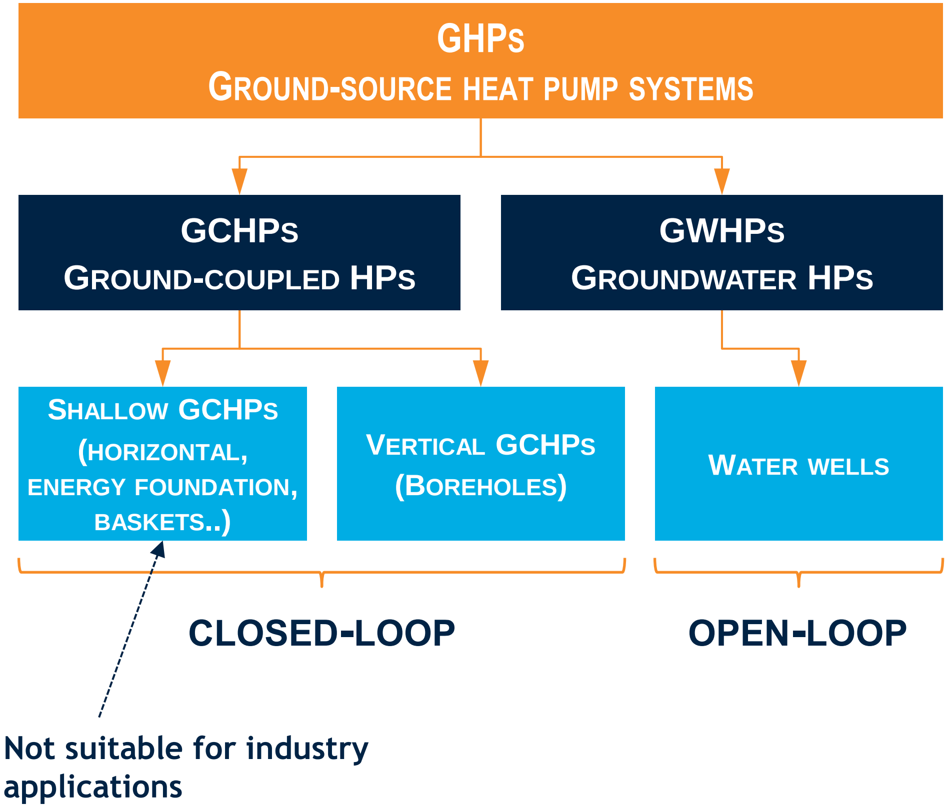
Ground-source heat pumps offer many layout alternatives, each with its own pros and cons. Both the technical feasibility and economic advantages are case-specific

II OVERVIEW OF THE GHP TECHNOLOGIES

HEAT PUMP TECHNOLOGIES

TECHNOLOGY	PROS	CONS
Air-source HPs	▪ Low CAPEX per kW	▪ Lower energy performances related to outdoor temperature
GWHPs	▪ Energy performances ▪ Low CAPEX per kW	▪ Clean groundwater availability ▪ Environmental concerns
V-GCHPs (boreholes)	▪ Energy performances ▪ Low environmental concerns	▪ High CAPEX per kW
H-GCHPs (horizontal)	▪ Good energy performances ▪ Low CAPEX	▪ Land requirements ▪ Not-suitable for large-capacity systems

TYPES OF GROUND-SOURCE HEAT PUMP SYSTEMS



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Electricity and natural gas prices in Bulgaria have more then doubled over the past years for some industrial customers groups. Price ratio of electricity and natural gas results in need for COP>2.

III Geothermal for industry

Electricity prices (BGN/MWh)

Group	Consumption (MWh/yr)		2020	2021	2022	2023
Band - I1	<20		240	313	465	414
Band - I2	20	< 500	222	301	449	382
Band - I3	500	<2 000	195	296	414	345
Band - I4	2 000	<20 000	184	279	384	327
Band - I5	20 000	<70 000	171	263	382	351
Band - I6	70 000	<=150 000	152	248	305	263
Band - I7	> 150 000		143	249	351	260

Price Ratio (2022 – 2023) ≈ 2.0 – 2.5

CO_2 Emission Ratio (2022 – 2023) ≈ 2.0

Source: BG Statistical Office

Natural gas prices (BGN/MWh)

Group	Consumption (MWh/yr)		2020	2021	2022	2023
Band - I1	0	278	74	108	204	177
Band - I2	278	2,778	66	102	214	163
Band - I3	2,778	27,778	51	89	197	141
Band - I4	27,778	277,778	38	79	195	135
Band - I5	277,778	1,111,111	35	78	237	133
Band - I6	1,111,111		n.a.	n.a.	n.a.	n.a.

COP >2 to provide advantages

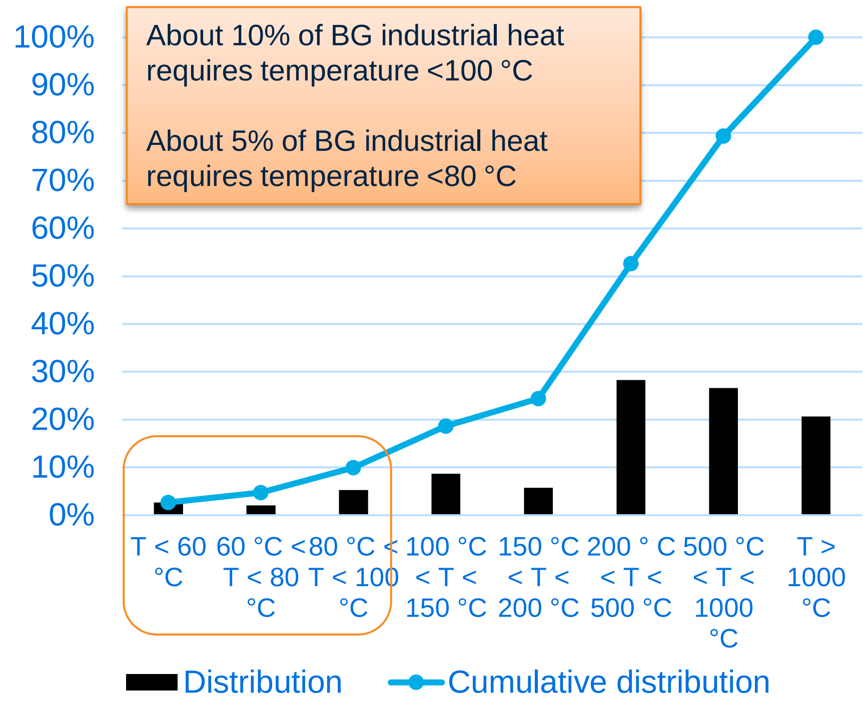
At ground-source temperatures (10/15C), current heat pump technology achieves a Coefficient of Performance (COP) > 2 for heat requirements up to 100° C

About 10% of BG industrial heat requires temperature <100 C, with chemical products and non-metallic mineral products showing the largest demand potential

III **GEOTHERMAL FOR INDUSTRY**

HEAT DEMAND IN BG INDUSTRIAL SECTORS

NO	SECTOR	% BG IND HEAT DEMAND	% HEAT DEMAND T≤80°C	% HEAT DEMAND T≤100°C
1	Food & Beverage	2%	<1 %	1 %
2	Wood & Wood products	2%	<1 %	1 %
3	Refined petroleum products	14%	<1 %	<1 %
4	Paper, pulp & print	7%	<1 %	2 %
5	Textile & Leather	<1%	<1 %	<1 %
6	**Chemical Products**	**40%**	**3 %**	**5 %**
7	Iron & Steel	3%	<1 %	<1 %
8	Pharmaceutical Products	< 1%	<1 %	<1 %
9	Non-ferrous	6%	<1 %	<1 %
10	Transport infrastructure	<1%	<1 %	<1 %
11	Plastic Products	<1%	<1 %	<1 %
12	**Non-metallic mineral products**	**24%**	**<1 %**	**<1 %**
13	Other chemical products	2%	<1 %	<1 %
	TOTAL:	**16.35 TWh / 59.5 PJ / 1.4 MTEP**		



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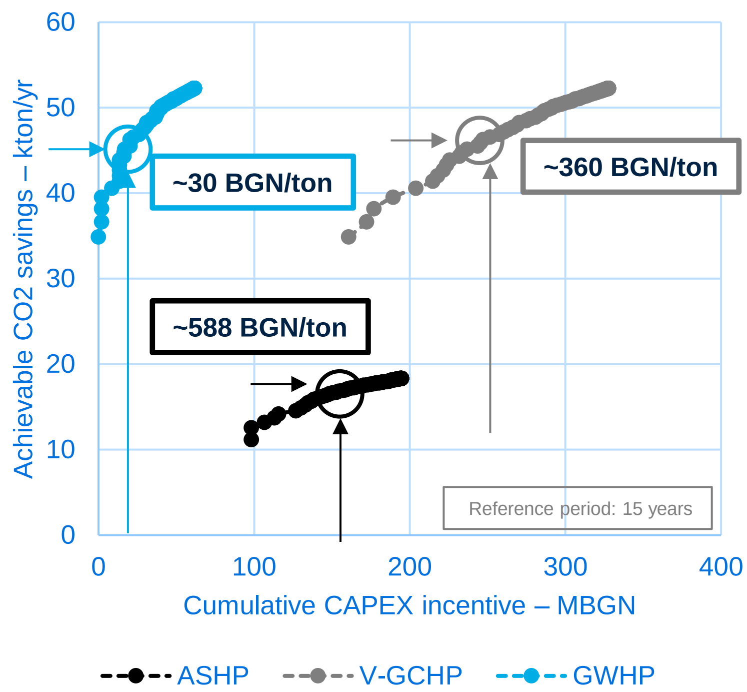
Industry: Supporting GHPs, especially GWHPs, results in higher environmental benefits and increased cost-effectiveness

ALL BG INDUSTRIAL SECTORS: INCREMENTAL EFFECT OF CAPEX FINANCIAL SUPPORT ON HP TECHNOLOGIES



- 132 Production sites
- 16,525,122 MWh/yr total heat demand* (~5% deliverable with GHPs)
- **~ 52.3 ktonCO2/yr possible savings** with GHP technologies
- CAPEX subsides required to make LCOH of GHP (HP + ground apparatus) equal to the LCOH of NG boilers
- On average, for each production site, the required support to make V-GHPs economically viable corresponds to about **66% of the initial CAPEX**.
- On average, for each production site, the required support to make GWHPs economically viable corresponds to about **21% of the initial CAPEX**.
- **A total of ~ 328 M BGN** is needed for **closed-loop systems** to support all the current 132 production sites and achieve the total technical potential
- **A total of ~ 62 M BGN** is needed for **open-loop systems** to support all the current 132 production sites and achieve the total technical potential

**From "Heat Demand Frequency"*

(!)Technical remark: open-loop systems are subjected to groundwater availability

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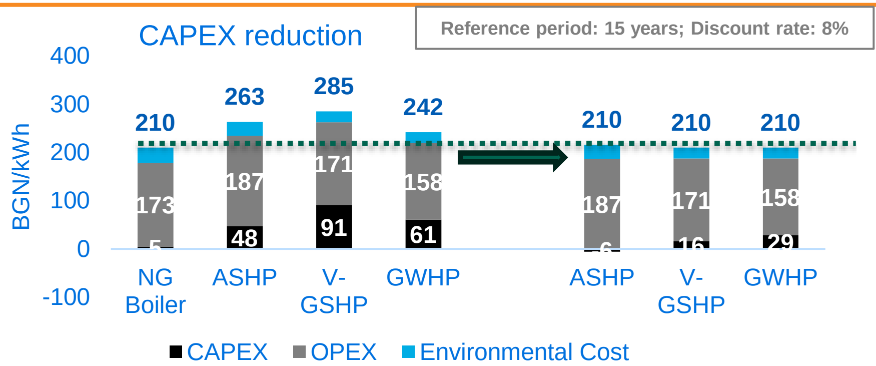
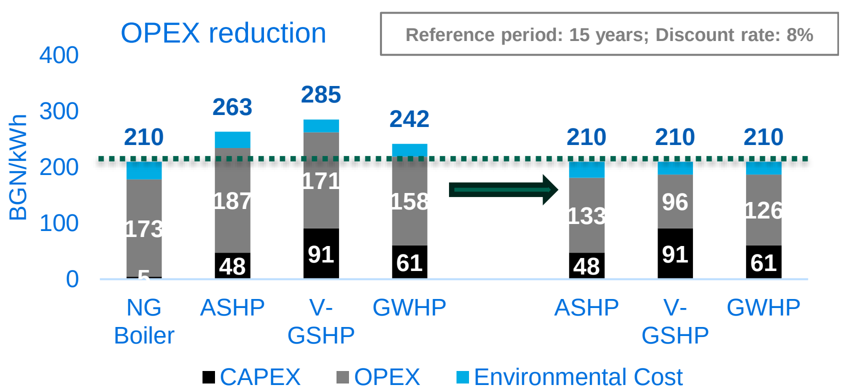
Industry: Support mechanism is required to make HP technologies competitive with NG boilers. Groundwater systems require lower levels of support that can be targeted at CAPEX reduction

III GEOTHERMAL FOR INDUSTRY

CHEMICAL PRODUCTS





COST OF AVOIDED EMISSIONS

- 11 Production sites
- 6,617,078 MWh/yr heat demand* (8% deliverable with GHPs)
- ~ **37.4** ktonCO2/yr possible savings with GHP technologies
- CAPEX subsidies required to make LCOH of GHP (HP + ground apparatus) equal to the LCOH of NG boilers
  - ~ 178 M BGN for closed-loop systems
  - ~ 6 M BGN for open-loop systems
  - The CAPEX support correspond to **56%-4%** the total CAPEX required to install V-GHP and GWHP, respectively
- OPEX subsidies required to make LCOH of GHP (HP + ground apparatus) equal to the LCOH of NG boilers
  - ~ 11 M BGN/yr for closed-loop systems
  - ~ 1 M BGN/yr for for open-loop systems
  - The OPEX support corresponds to **33%-1%** the yearly fuel expenditure to run V-GHP and GWHP, respectively

**From "Heat Demand Frequency"*

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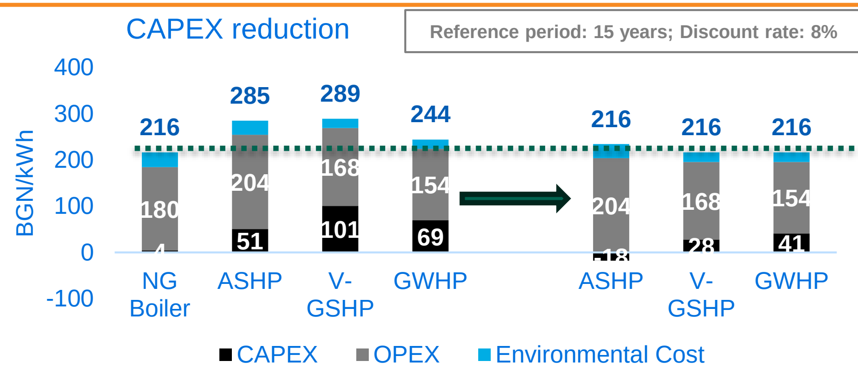
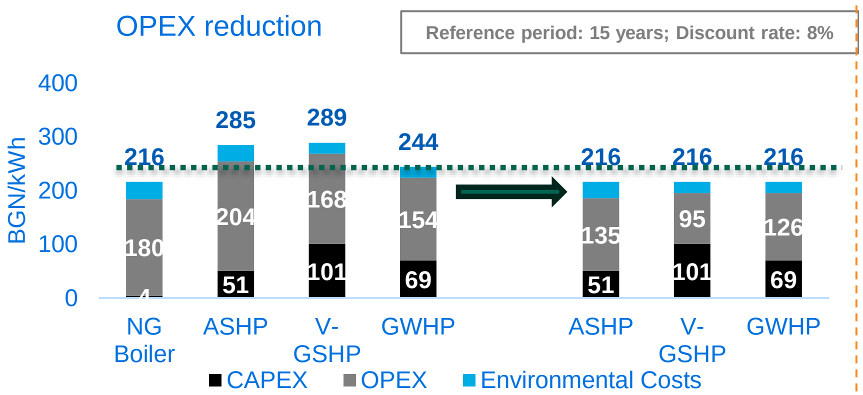
Industry: Support mechanism is required to make HP technologies competitive to NG boilers (LCOH). Groundwater systems require lower levels of support that can be targeted at CAPEX reduction

III **GEOTHERMAL FOR INDUSTRY**

NON-METALLIC MINERAL PRODUCTS





COST OF AVOIDED EMISSIONS

- 22 Production sites
- 3,969,468 MWh/yr heat demand* (1% deliverable with GHPs)
- **~ 3.5 ktonCO2/yr** possible savings with GHP technologies
- CAPEX subsides required to make LCOH of GHP (HP + ground apparatus) equal to the LCOH of NG boilers
  - ~ 17 M BGN for closed-loop systems
  - ~ 3 M BGN for open-loop systems
  - The CAPEX support correspond to **53%-12%** the total CAPEX required to install V-GHP and GWHP, respectively
- OPEX subsides required to make LCOH of GHP (HP + ground apparatus) equal to the LCOH of NG boilers
  - ~ 2 M BGN/yr for closed-loop
  - ~ 1 M BGN/yr for open-loop
  - The OPEX support correspond to **43 %- 6 %** the yearly fuel expenditure to run V-GHP and GWHP, respectively

**From "Heat Demand Frequency"*

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Buildings: The conversion to GHP can achieve notable energy savings of 5,443 GWh and CO2 reductions of 1.33 million tons, with the greatest potential observed in SFH and MAB.

IV GEOTHERMAL IN BUILDINGS, TECHNICAL POTENTIAL

Existing fuel type by building	Targeted buildings area, mil. m2	Share of total heated area2	Investments in GHP, mil. BGN	Energy savings, GWh	Savings of CO2, ton CO2e	Savings of PM2.5, ton
Single family building	**54.9**	**20.6%**	**13,769**	**3,977**	**930,683**	**10,260**
Coal	0.0	0.0%	3	1	314	2
Delivered Heat	1.2	0.5%	311	50	14,279	1
Electricity	8.4	3.1%	2,096	411	199,973	4
Natural Gas	4.0	1.5%	995	170	31,040	0
Pellet	8.3	3.1%	2,073	459	35,829	134
Wood	33.0	12.4%	8,292	2,886	649,248	10,118
Multi-apartment building	**20.1**	**7.5%**	**2,688**	**935**	**253,581**	**23**
Delivered Heat	17.3	6.5%	2,317	799	228,721	22
Natural Gas	2.8	1.0%	371	136	24,860	0
Public building	**7.4**	**2.8%**	**2,076**	**531**	**142,510**	**13**
Delivered Heat	6.2	2.3%	1,741	440	126,067	12
Natural Gas	1.2	0.4%	334	90	16,443	0
Grand Total	**82.4**	**30.9%**	**18,532**	**5,443**	**1,326,774**	**10,296**

- Grant levels necessary to make the installation of a ground source heat pump in EE renovated buildings competitive and financially viable:
  - **Single-family buildings 50% CAPEX**
  - **Multiapartment buildings 30% CAPEX**
  - **Public buildings 40% CAPEX**
- Deployment of GHP in an already EE renovated building reduces the risk of system oversizing and **further reduces the operating and CAPEX costs**, but the initial investment would still require a targeted support scheme
- In the case of an MAB, the total operating heating cost per square meter can be up to three times lower if GHP is installed in a building that has undergone thermal renovation.

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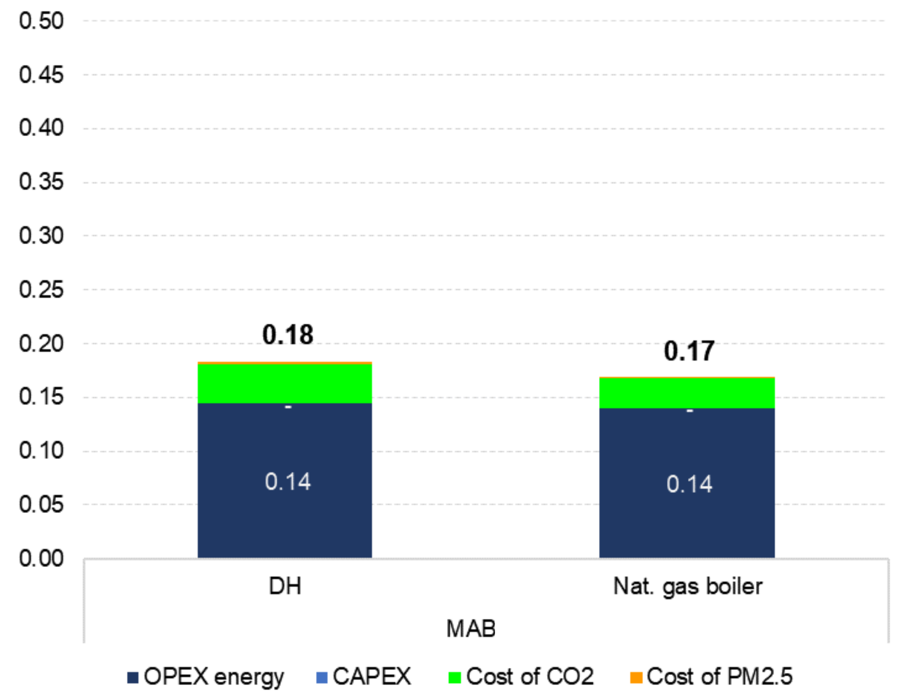
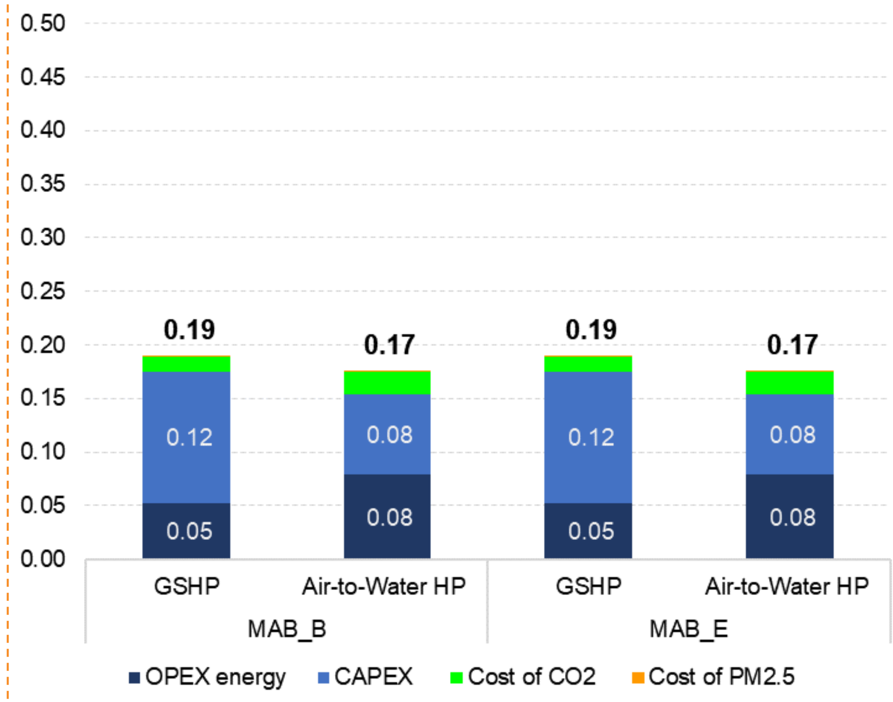
Renovated and Non-Renovated MAB – LCOH from heat pump systems, despite higher initial investments and installation costs, remains competitive with the costs of heat associated with district heating and natural gas boilers

IV **GEOTHERMAL FOR HOUSEHOLDS IN MULTI-APARTMENT BUILDING (MAB)**

LCOH OF EXISTING HEAT SOURCE BGN/KWH



LCOH OF REPLACED HEAT SOURCE BGN/KWH



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