Web-Based Geothermal Energy Potential Mapping and Analysis for Berlin(1)

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Motivation

According to estimates by the Fraunhofer Institute, up to **12.8%** of Berlin's heating energy demand can be met by using Ground Source Heat Pumps (GSHP) by 2035[1].

This figure highlights the potential for expanding geothermal planning using Borehole Heat Exchanger (BHE) fields, which are central to most GSHP systems. However, integrating this potential into daily operations is challenging, as the required estimations are time-consuming, costly, and require expert knowledge

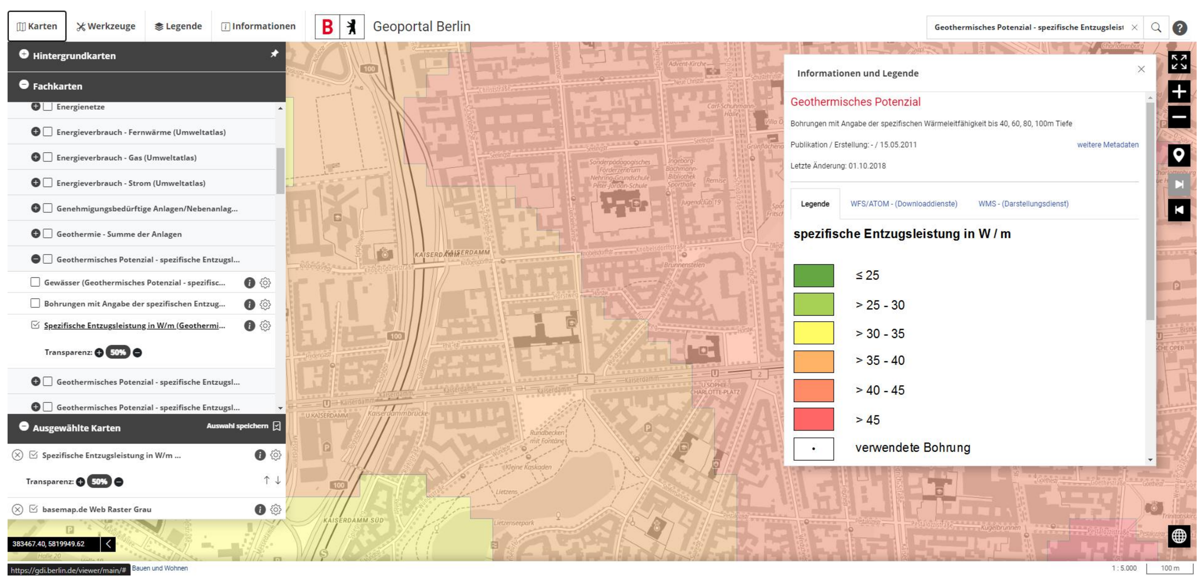

Figure 1: The geoportal from Senate Department for Urban Development, Building and Housing of Berlin [2]

Automation

Geothermal planners currently need to individually access all relevant information through geoportals and manually aggregate the data for each specific use case

GERMA

(Geothermal Energy Resource Mapping and Analysis)

- Land parcel identification
- Thermal conductivity analysis
- Ground temperature measurements
- Estimated heat extraction potential
- Water protection zones
- Depth restrictions
- Legislative regulations

Figure 2: Desired Features of the Application

Objectives

- Development of a tool to provide an initial estimate of the geothermal potential for a Borehole Heat Exchanger (BHE) field
- The estimation should be based on land parcel data and BHE-specific parameters
- Creation of an easy-to-use web interface for interacting with the tool
- Calculation of the potential heat extraction for the Berlin area under various scenarios to determine how much of the city's heat demand could be met using BHE systems alone

Methodology

Data acquisition and actuality

- Only publicly available data is used
- Most of the data is provided by the Senate Department for Urban Development, Building, and Housing (SenSBW) of Berlin [2]
- The geospatial data is stored in a local database and spatially indexed to ensure
- fast performance
- Data is regularly updated by retrieving it from SenSBW servers

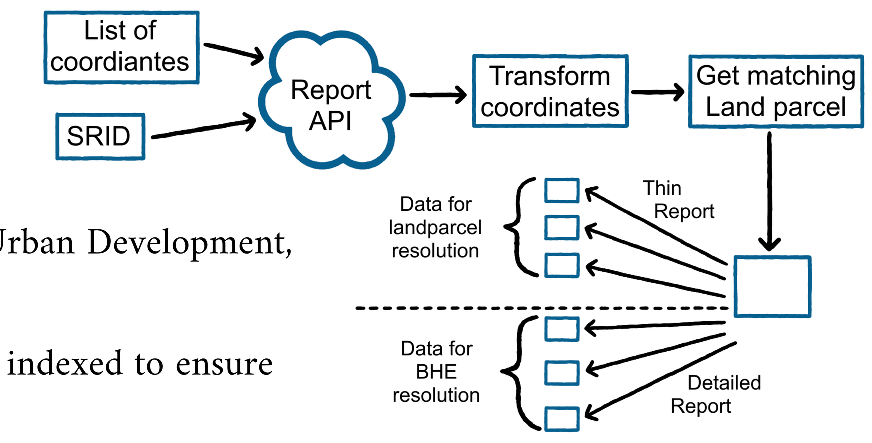

Figure 3: Report creation, based on the API. Reports can be generated as thin or detailed reports

Automatic BHE modelling

Based on the prior calculated usable area for BHE deployment, the positioning of individual BHE units can be modeled. A custom algorithm was developed for this purpose, which optimizes the placement of BHEs by minimizing the area each BHE occupies within the available usable area.

- Models BHE with a distance of 6 meter
- This BHE modeling allows for the determination of parameters at the resolution of individual BHEs.

Usable area determination

The area available for Borehole Heat Exchanger (BHE) installation, referred to as the usable area, is calculated based on technical and established standards set by the Senate Department for the Environment, Transport, and Climate Protection of Berlin [3], along with custom criteria:

- 3 meter distance from the land parcel boundary
- 2 meters from any existing buildings
- 4 meter distance from trees

The total usable area is determined by applying these restrictions, which forms the basis for subsequent BHE simulations.

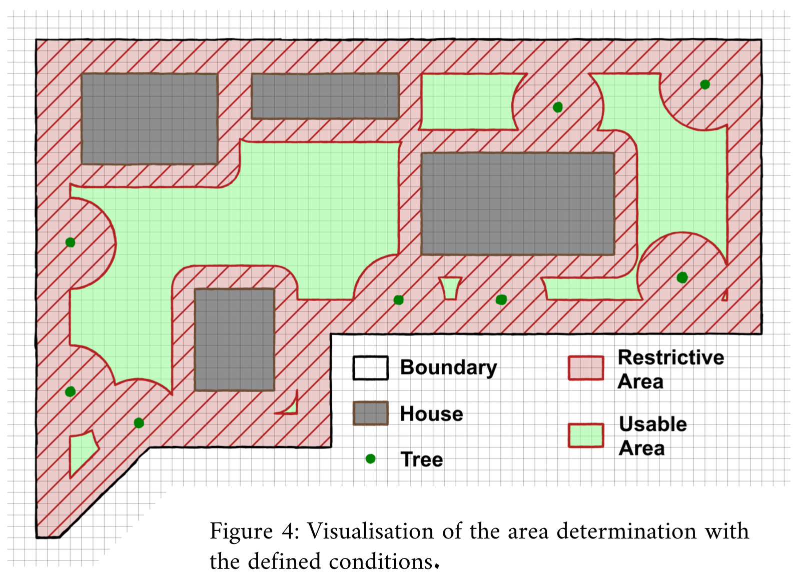

Figure 4: Visualisation of the area determination with the defined conditions.

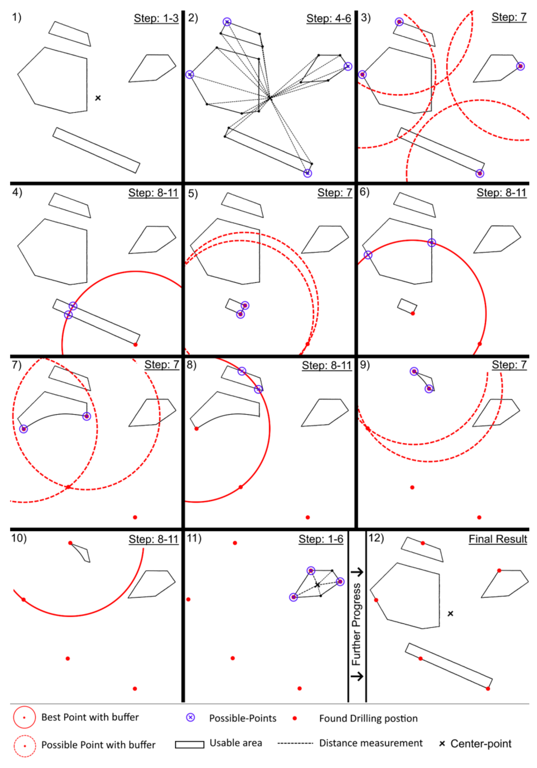

Figure 5: Stepwise visualisation of the area minimising point positioning algorithm for multipolygon structures. The area used is the Usable-Area prior computed.

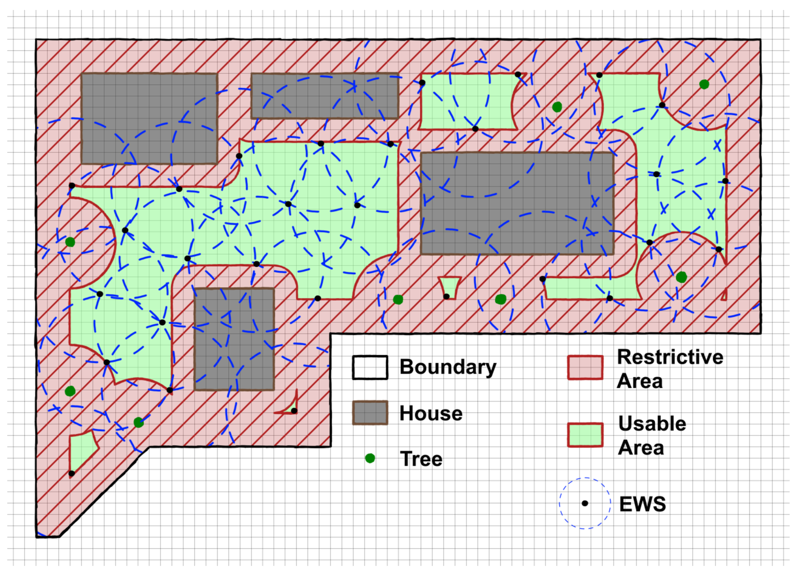

Figure 6: Visualisation of the area determination with the defined conditions, with BHE.

Application results

Report

- A report can be generated using the web interface by simply clicking on the map
- The selected coordinates are sent via an API to the server, which determines the corresponding land parcels
- For these land parcels, area determination and BHE modeling are performed
- For all simulated BHEs, geothermal parameters are calculated and summarized
- For all simulated BHEs, geothermal parameters are calculated and summarized. These parameters contain an overview of commonly used geothermal information, the estimated extraction rate of all BHEs, relevant regulations, and a custom rating.

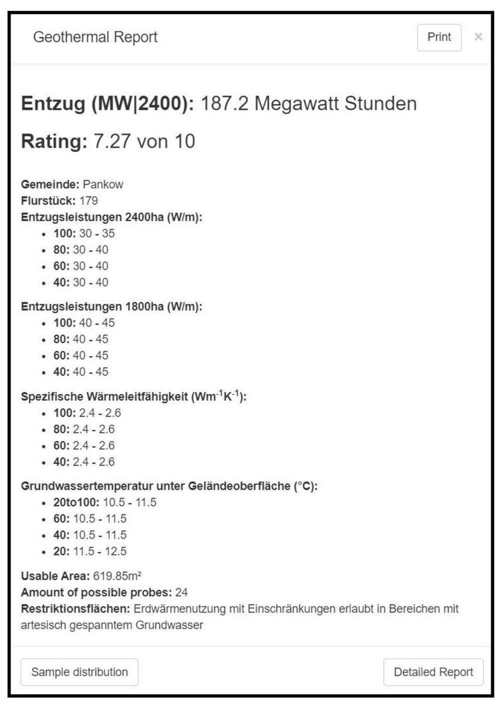

Figure 7: Detailed-Report shown in the frontend application. It includes additional information to the extraction value, the custom rating and the potions of the modelled BHE (not shown in this graphic)

Webinterface

- Provides information for every point in the area of berlin
- Easy to work with, even for non-experts
- Can be made public when wanted in the future
- Can be extended in the future to support also other federal states in Germany

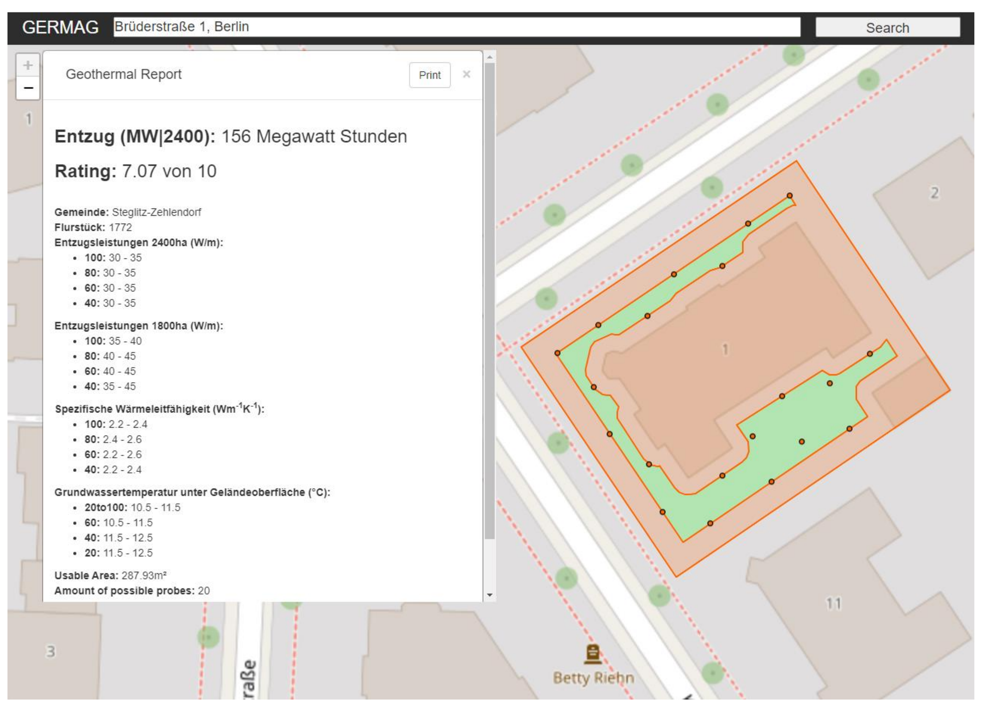

Figure 8: Webinterface from the GERMA application

Scientific evaluation

- Approximately **45.78%** of Berlin's domestic heating demand could be met through Borehole Heat Exchanger (BHE) fields located in residential areas
- With current legislation and the utilization of industrial and commercial areas, BHE systems could cover **33.97%** of Berlin's overall heat demand
- Should legislative changes permit the use of state-owned public areas, it would be possible to meet the entirety of Berlin's domestic heating demand, potentially covering over **58.86%** of its total heating demand.

	Residential scenario	**Industrial and commercial scenario**	**Public area scenario**
BHE modelled			
Total amount	3,350,967	4,774,225	8,163,872
Usable area			
Total (Km^2)	89.73	137.18	252.99
Percentage share of Berlin's area	10.07%	15.40%	28.40%
Heat extraction share of BHEs in percent			
< 30 (W/m)	4.58%	3.90%	4.38%
$30 - 35$ (W/m)	69.00%	69.57%	68.12%
> 35 (W/m)	26.42%	26.53%	27.50%
Total annual heat extraction in TWh (Terrawatt hours)	8.76	12.47	21.60
Coverage by heat demand			
Berlin-2020 (36.70 TWh)	23.87%	33.97%	58.86%
Berlin-2035 (32.15 TWh)	27.25%	38.78%	67.19%
Housing only (19.14 TWh)	45.78%	65.15%	100% *(112.87%)*

Figure 9: Total heat extraction that can be covered for every sector by the different BHE deployment scenarios

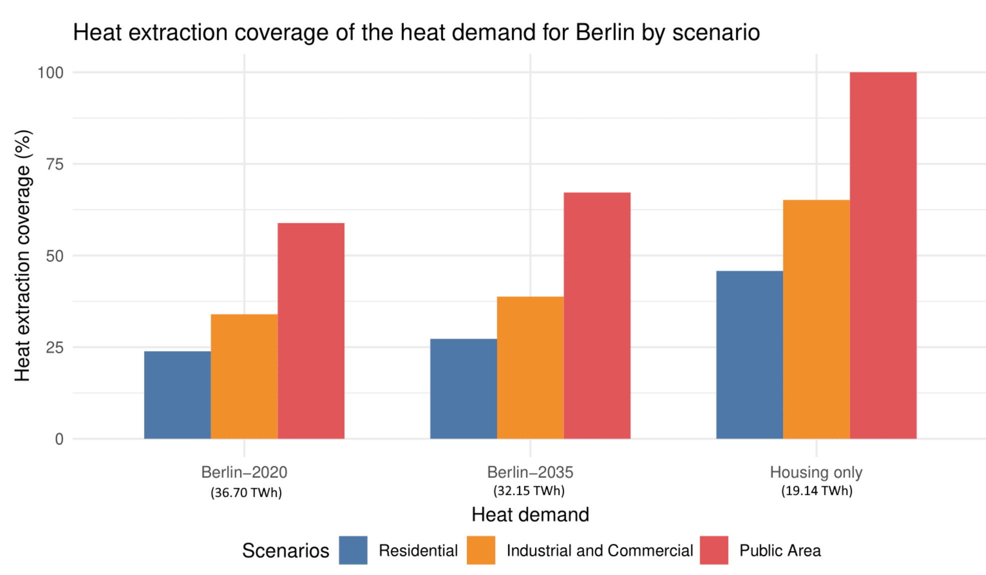

Figure 10: Table of the scientific results
Scenarios:
- Residential Scenario: Focuses on residential areas only.
- Industrial and Commercial Scenario: Includes residential, industrial, and commercial areas.
- Public Area Scenario: Covers residential, industrial, commercial, public spaces, and other multifunctional areas.

Conclusion

- Berlin's heat demand can be significantly covered through the use of Borehole Heat Exchanger (BHE) fields
- The developed application is a valuable tool for daily planning operations
- Applications like this are also relevant for non-experts, as making such information accessible to all citizens in an easily understandable format is crucial for the future expansion of renewable energies

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Scan for the complete master thesis

References

[1] Egelkamp, Robert, Lina Wett, and Anna Kallert. "Potenzialstudie klimaneutrale Wärmeversorgung Berlin 2035." (2021).

[2] Geoportal Berlin. (n.d.). Geoportal Berlin viewer. Senatsverwaltung für Stadtentwicklung, Bauen und Wohnen von Berlin . Retrieved October 17, 2024, from https://gdi.berlin.de/viewer/main/#

[3] Senatsverwaltung für Umwelt, Verkehr und Klimaschutz. Leitfaden Erwärmenutzung in Berlin. Technical report, Senatsverwaltung für Umwelt, Verkehr und Klimaschutz, 2020.

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