

Maps of shallow geothermal potential

Project TransGeoTherm & other examples

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Państwowy Instytut Geologiczny
Państwowy Instytut Badawczy

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COST – GABI workshop, Lisbon
10.12.2015

Why we need maps of shallow geothermal potential ?

- The aim of producing geothermal maps is to provide cartographic image for a certain area, showing thermal properties of bedrocks
- Geothermal maps are used for evaluation of location suitability: opportunities as well as barriers and restrictions in developing shallow geothermal energy systems, especially ground source heat pumps (GSHP)
- Geothermal maps may serve as a decision making or auditing tool, which allow proper assessment of renewable energy sources at local and regional scale
- Geothermal maps can be used by local authorities, planners as well as business sector (producers and installers of GSHP) and individual investors

Basic types of shallow geothermal potential maps

TYPE 1

- general maps based on reprocessed geological and hydrogeological data indicating qualitative / descriptive categorizing of subsurface rocks
- Type 1 qualitative maps may present:
 - terrain with perfect / good / poor or bad rock properties and showing places with existing restrictions or exclusions considering use of GSHP,
 - terrains suitable for installation of different type of GSHP, eg. for „open” (water/water) systems, and „closed” systems (glycol/water) with differentiation into „horizontal collectors” and „vertical probes / heat exchangers”



Basic types of shallow geothermal potential maps

TYPE 2

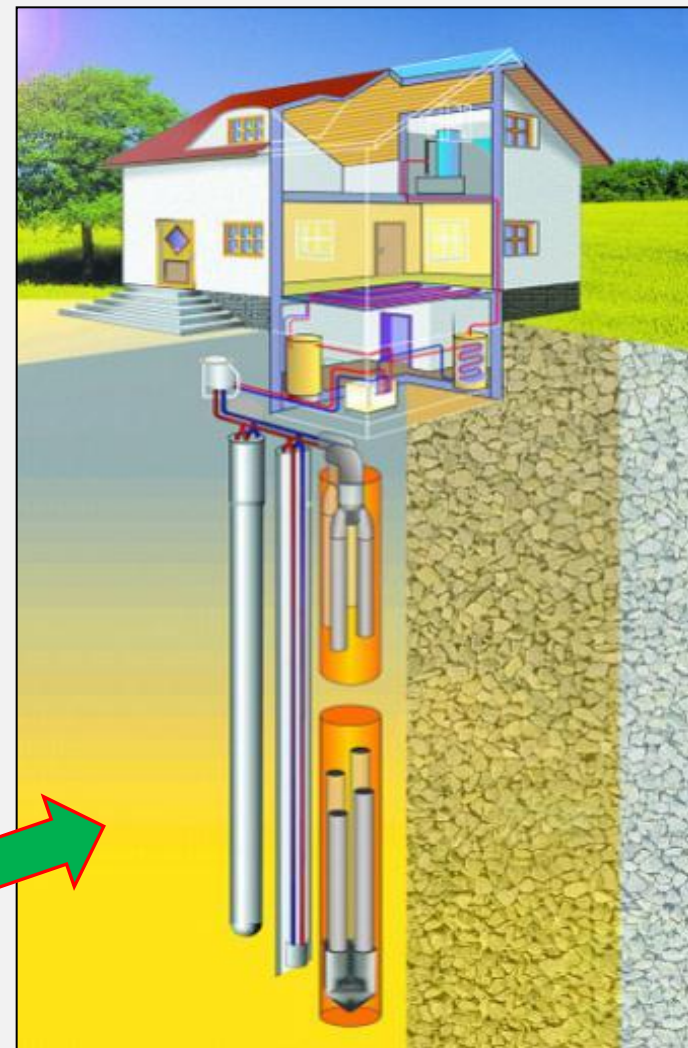
- detailed maps of geothermal potential, presenting quantitative estimation of the thermal parameters of rocks, usually to a max. depth of c. 130 m
- the maps allow planning the amount of power and technical requirements of the GSHP, especially for the pumps with vertical heat exchanger
- TYPE 2 quantitative maps can be divided into:
 - maps based on the value of thermal conductivity of rocks expressed in **W / m*K**
 - maps based on the value of heat extraction rate expressed in **W / m**
 - maps based on the value of thermal power expressed in **kWh / m**



Why we need shallow geothermal energy:
because in numerous part of Europe the air is very polluted by smog
emitted from individual heating installations using coal !!!



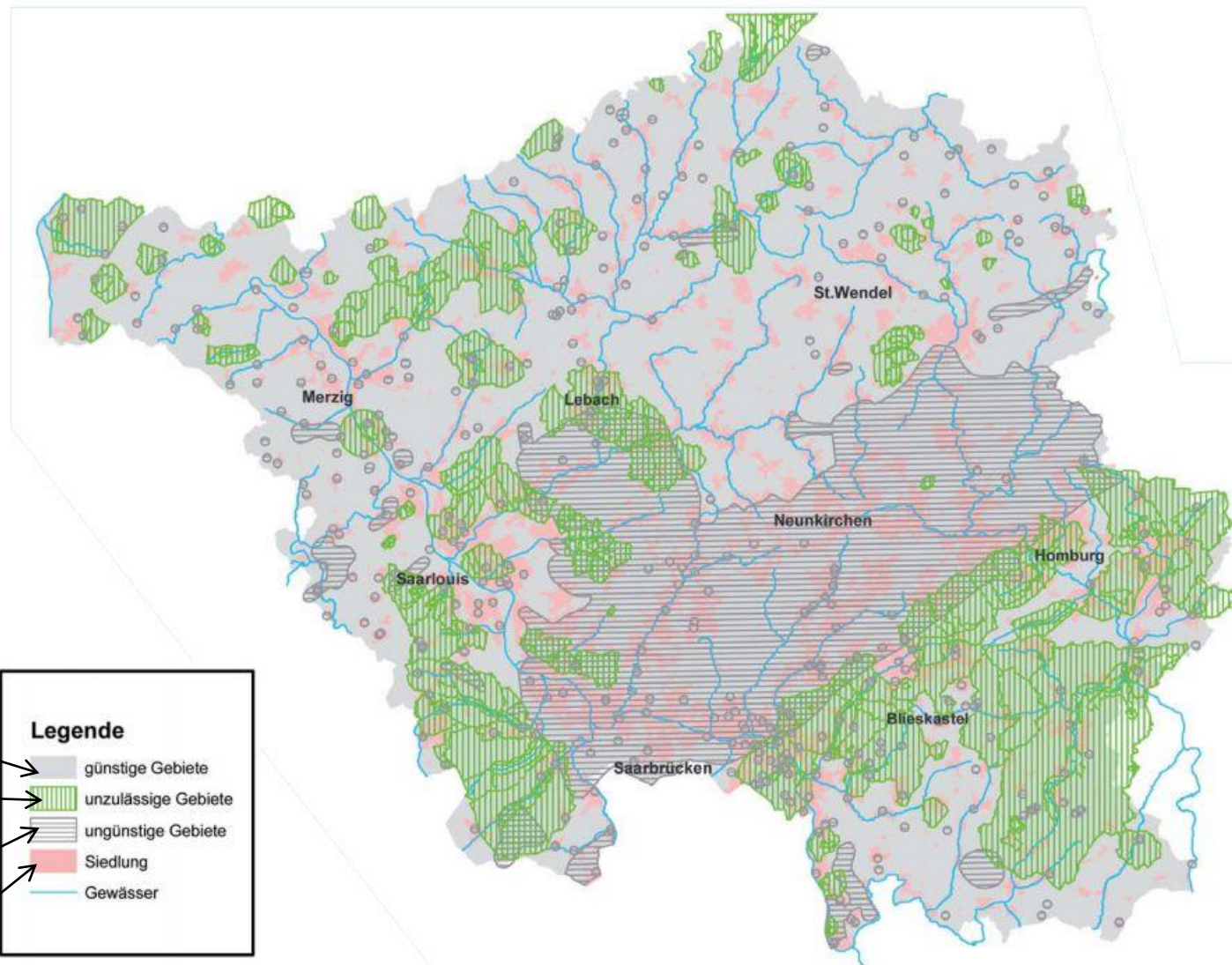
We can clean the air
when old heating systems
are replaced by renewable energy sources like
GROUND SOURCE HEAT PUMPS



Examples of TYPE 1 qualitative geothermal maps



Land Saar: simplified map showing site assessment for installation of GSHP without specified conditions of classification



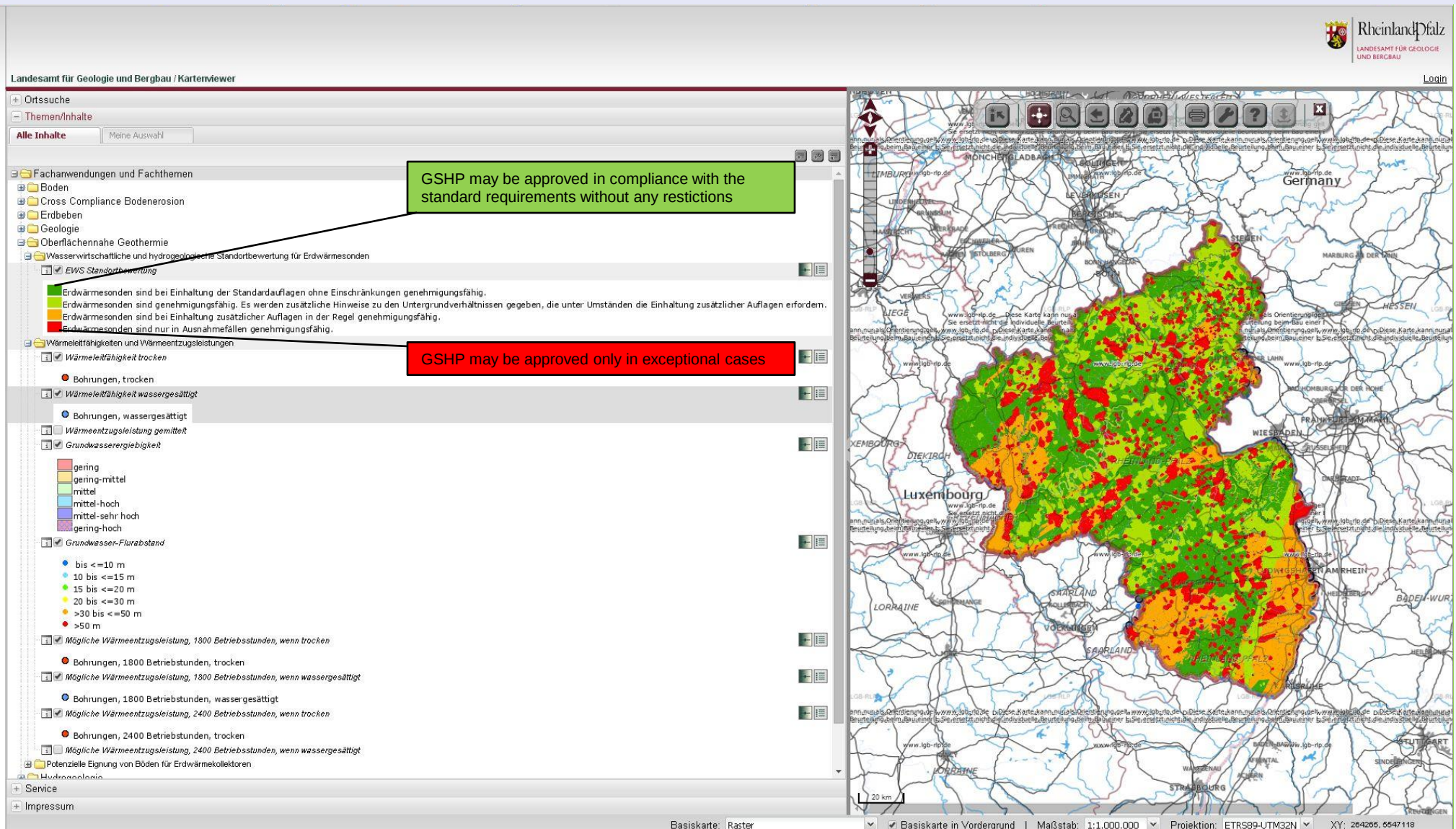
favorable terrain

inadmissible terrain

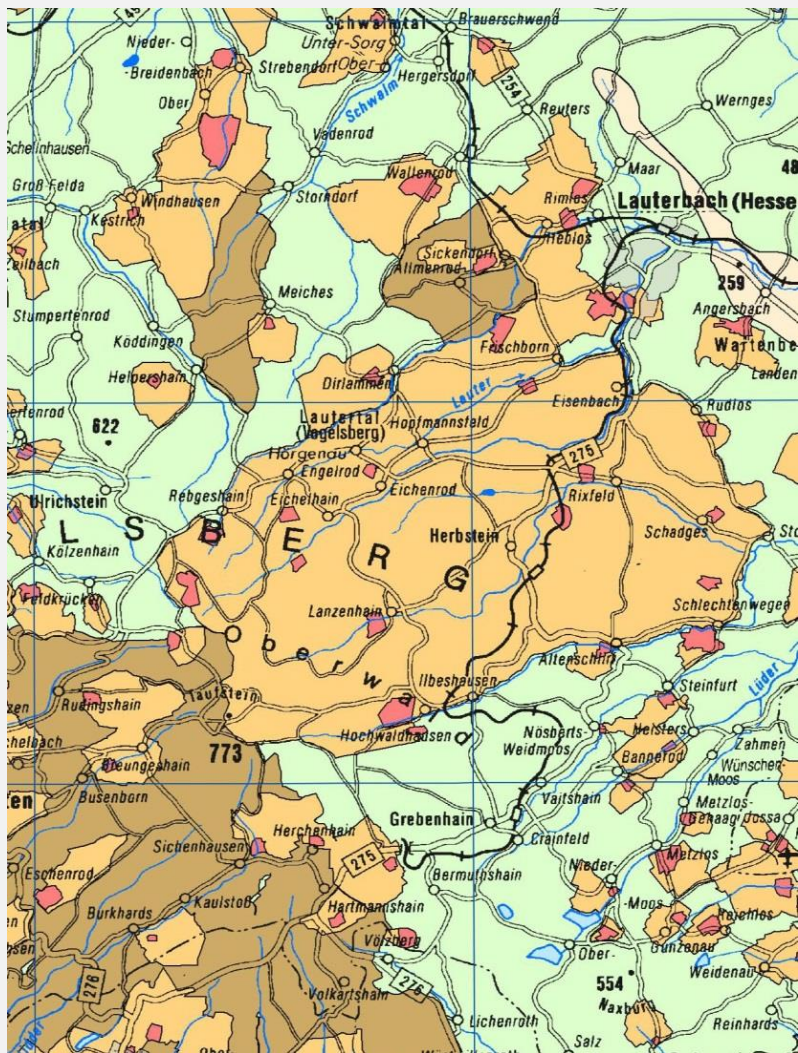
adverse terrain

settlements

Land RheinePfalz: map of site assessment for installation of GSHP with specified legal requirements and hydrogeological conditions



Land Hessen: Map of site assessment for installation of GSHP based on hydrogeology and water management conditions



Hessisches Landesamt für Umwelt und Geologie

**Hydrogeologische und
wasserwirtschaftliche
Standortbeurteilung
für die Errichtung von
Erdwärmesonden in Hessen**

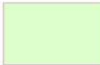
1 : 200 000

Standortbeurteilung für die Errichtung von Erdwärmesonden in Hessen

(Bearbeitungsstand: 08. März 2012)

Bearbeitung: Dezemat W4 - Hydrogeologie, Grundwasser
Ansprechpartner: Dr. Sven Rumohr

favorable



Hydrogeologisch und wasserwirtschaftlich günstig

Gebiete mit mittlerer bis geringer Wasserdurchlässigkeit, ohne eine wesentliche Stockwerkstrennung und ohne Vorkommen von höher mineralisierten Grundwässern bzw. CO₂-Aufstiegszonen bei gleichzeitiger Lage außerhalb von Wasser- und Heilquellenschutzgebieten.



Hydrogeologisch ungünstig

Gebiete mit nennenswerten Grundwasser-, Mineralwasser- oder Heilwasservorkommen, die durch eine Grundwasserüberdeckung geschützt werden. Ungünstig sind auch Gebiete mit hoher Wasserdurchlässigkeit der Gesteine, einer wesentlichen, d.h. weiträumigen Stockwerkstrennung, mit Aufstiegszonen von CO₂ oder hoch mineralisierten Wässern oder mit artesisch gespannten Grundwasservorkommen sowie Tiefgrundwasserleiter (insbesondere im Festgestein), die nicht angefahren oder durchteuft werden sollten. Ungünstig sind zudem Gebiete mit quelfähigen Gesteinen, wie Anhydrit und bestimmten Tonen.

relevant



Wasserwirtschaftlich relevant (siehe **Wichtiger Hinweis**)

Gebiete in den Zonen WSG IIIB und HQSG III/2.



Wasserwirtschaftlich ungünstig (siehe **Wichtiger Hinweis**)

Gebiete in den Zonen WSG III und IIIA sowie HQSG III, III/1 und B.



Hydrogeologisch unzulässig

Gebiete, in denen aufgrund ungünstiger hydrogeologischer Gegebenheiten (s. o.) und nach bereits erfolgten Einzelfallprüfungen davon ausgegangen wird, dass die Errichtung von Erdwärmesonden in jedem Fall zu einer schädlichen Beeinflussung des Grundwassers führt.



Wasserwirtschaftlich unzulässig

Gebiete in den Zonen WSG I, II und vereinzelt IIIA sowie HQSG I, II und A.

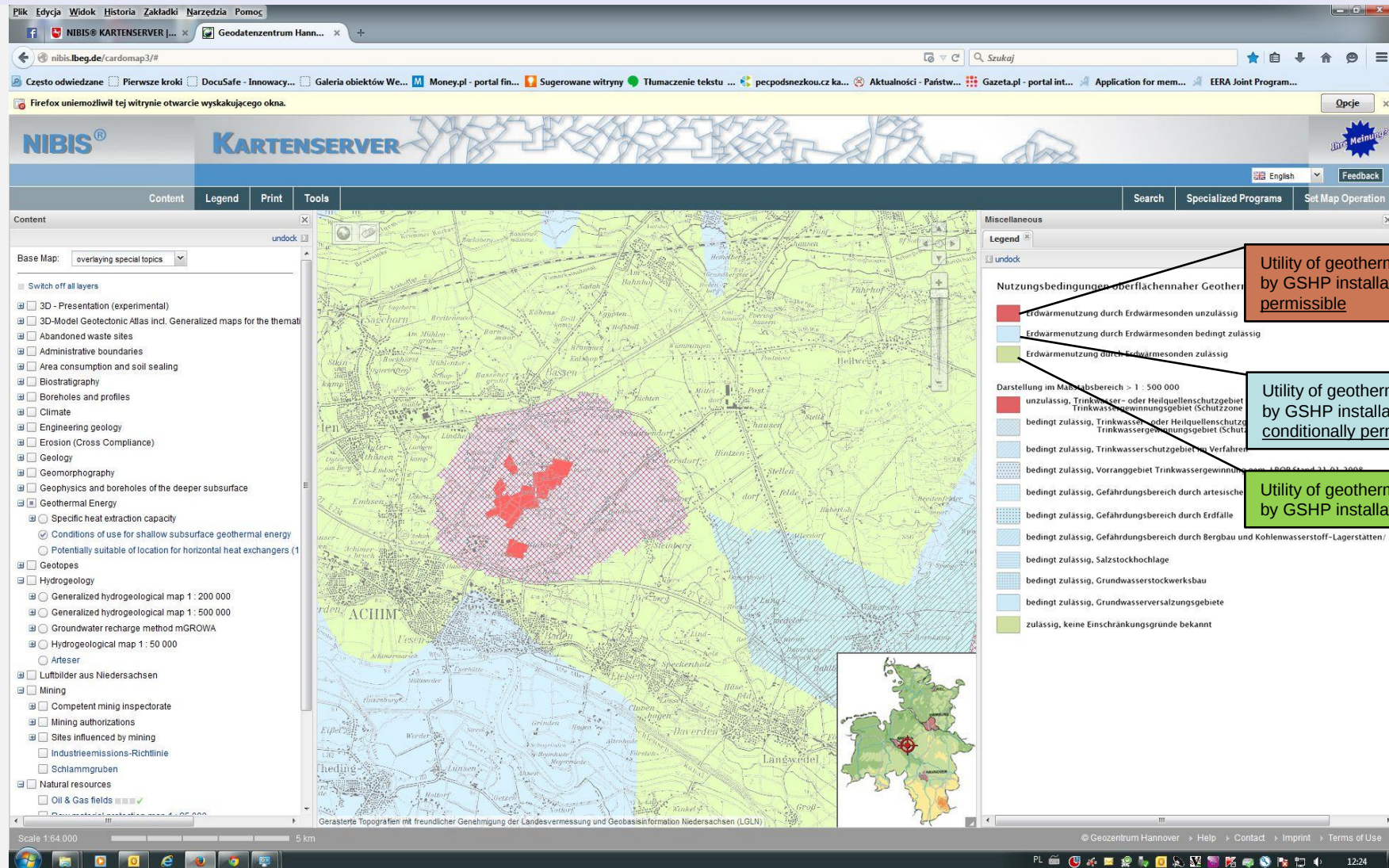
inadmissible



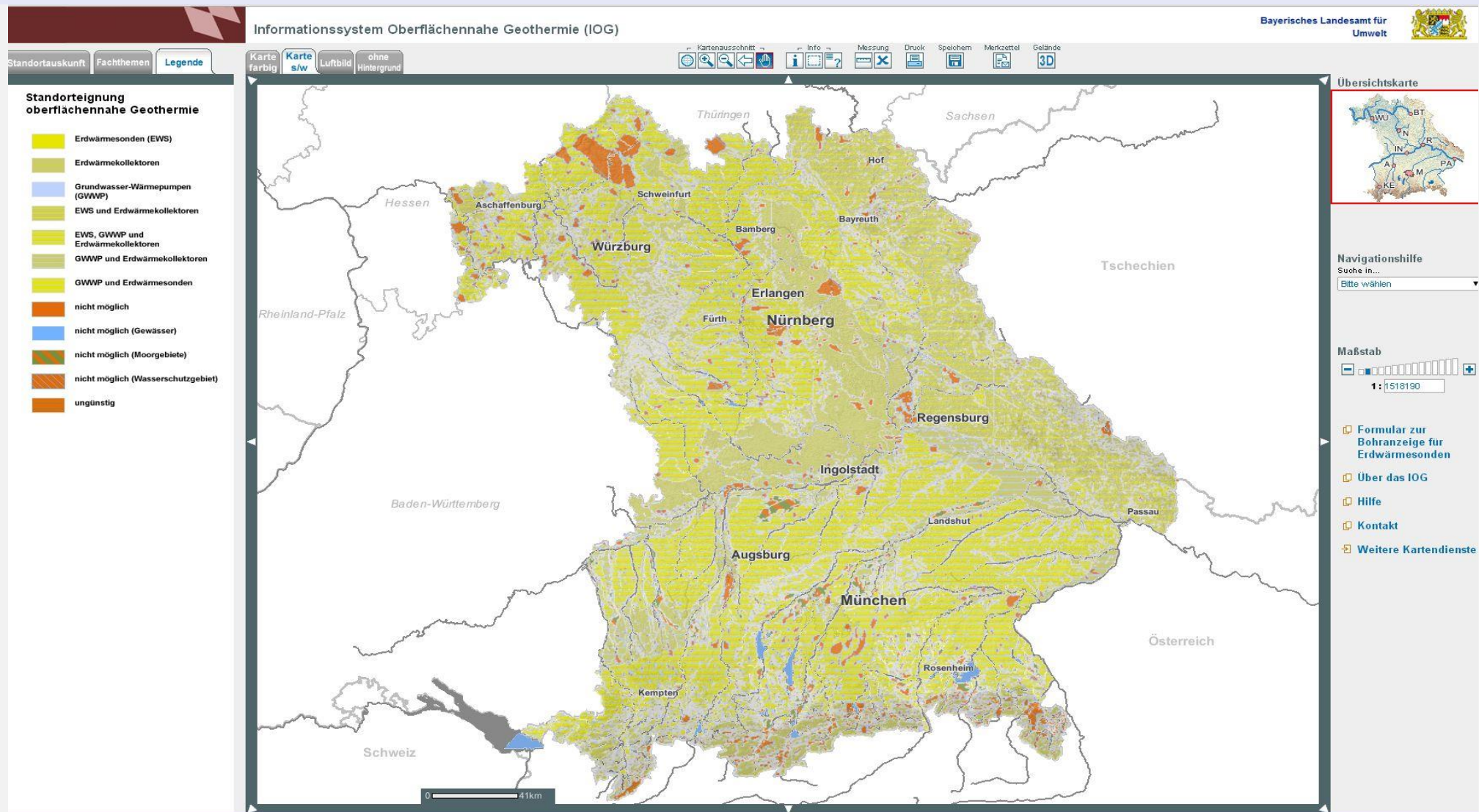
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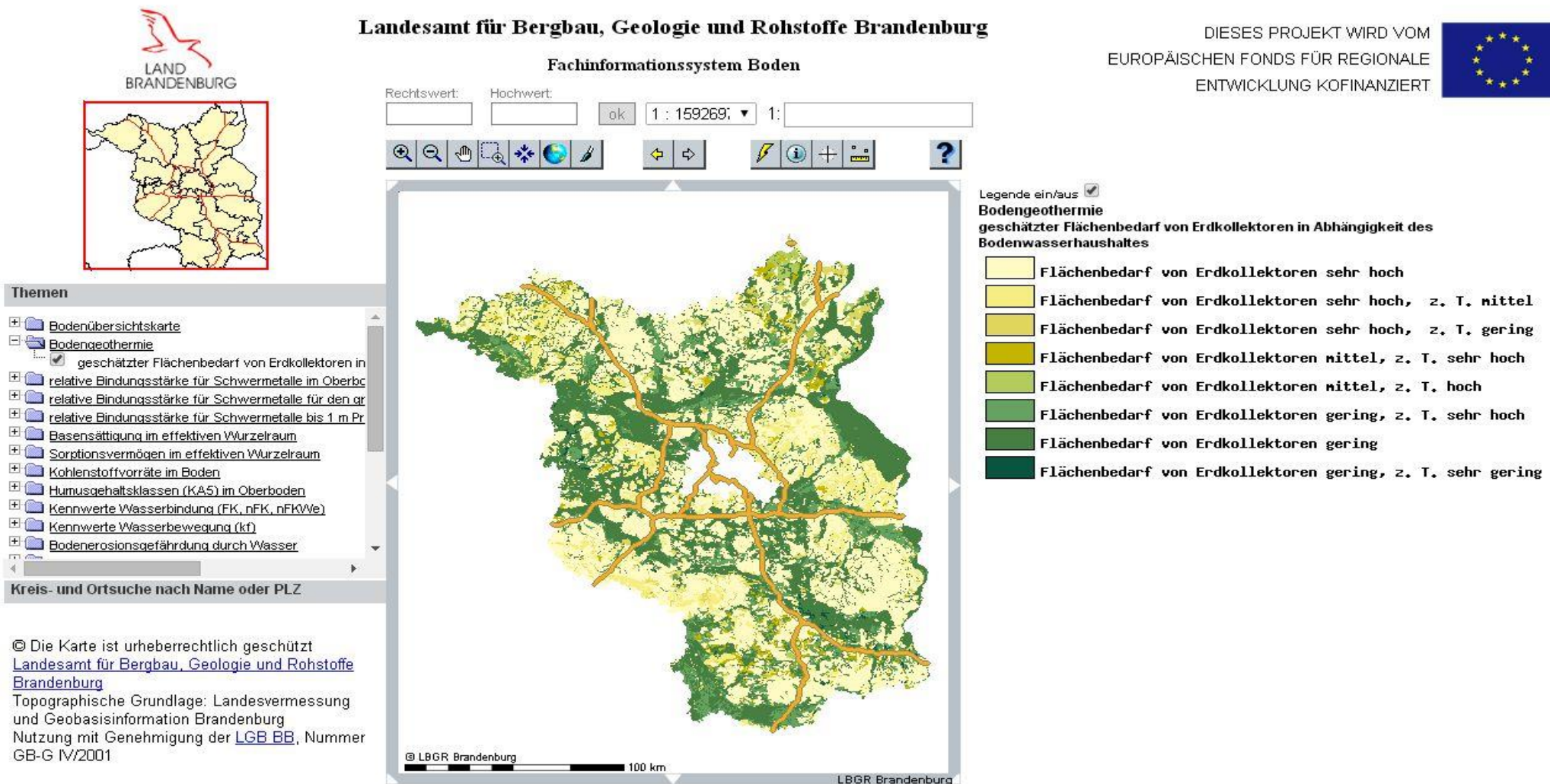
Land Lower Saxony: map of site assessment for installation of GSHP based on hydrogeology and water management conditions



Land Bavaria: Map of location suitability for installation of different systems of GSHP based on geology, hydrogeology and water management conditions



Land Brandenburg: map of site assessment for installation of GSHP with horizontal collectors based on hydrogeology and geothermal conditions of soil



Examples of TYPE 2 quantitative geothermal maps

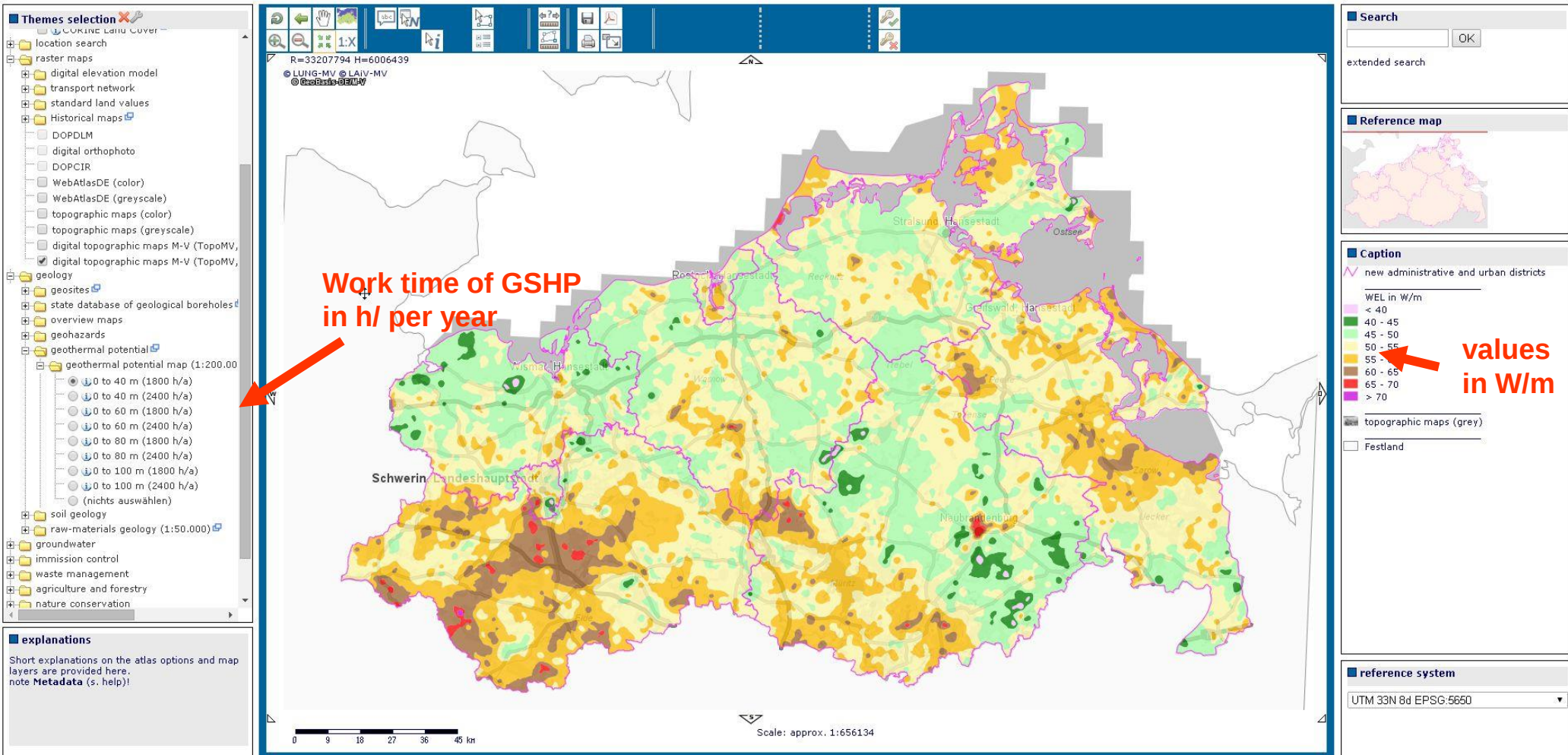


Land Mecklenburg-Vorpommern: map of geothermal potential based on geological 3D model and calculated values of heat extraction rate [W/m], for depths of 40, 60, 80 and 100m; for 1800 and 2400 h per year of GSHP work time

Environmental Geodata Services Mecklenburg-Vorpommern
State Agency of Environment, Nature Protection and Geology



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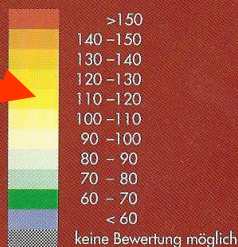
Land Rhine - North Westfalia: map of geothermal potential based on geological 3D model and calculated values of power extraction rate [kWh/m], for depths of 40, 60, 80 and 100m; for 1800 or 2400 h per year of GSHP work time

Geothermisches Potenzial

in Nordrhein-Westfalen

Geothermische Ergiebigkeit für den oberflächennahen Bereich

in $\text{kWh}/(\text{m} \cdot \text{a})$ bei 2400 Betriebsstunden und Sondenlängen von 40 m



Geothermie

- ist unerschöpflich und klimaschonend
- liefert Wärme, Kälte und auch Strom
- ist ganzjährig verfügbar – im Sommer und Winter, bei Tag und bei Nacht
- ist bei fachgerechter Ausführung unbedenklich für Boden und Grundwasser
- ist nahezu überall nutzbar

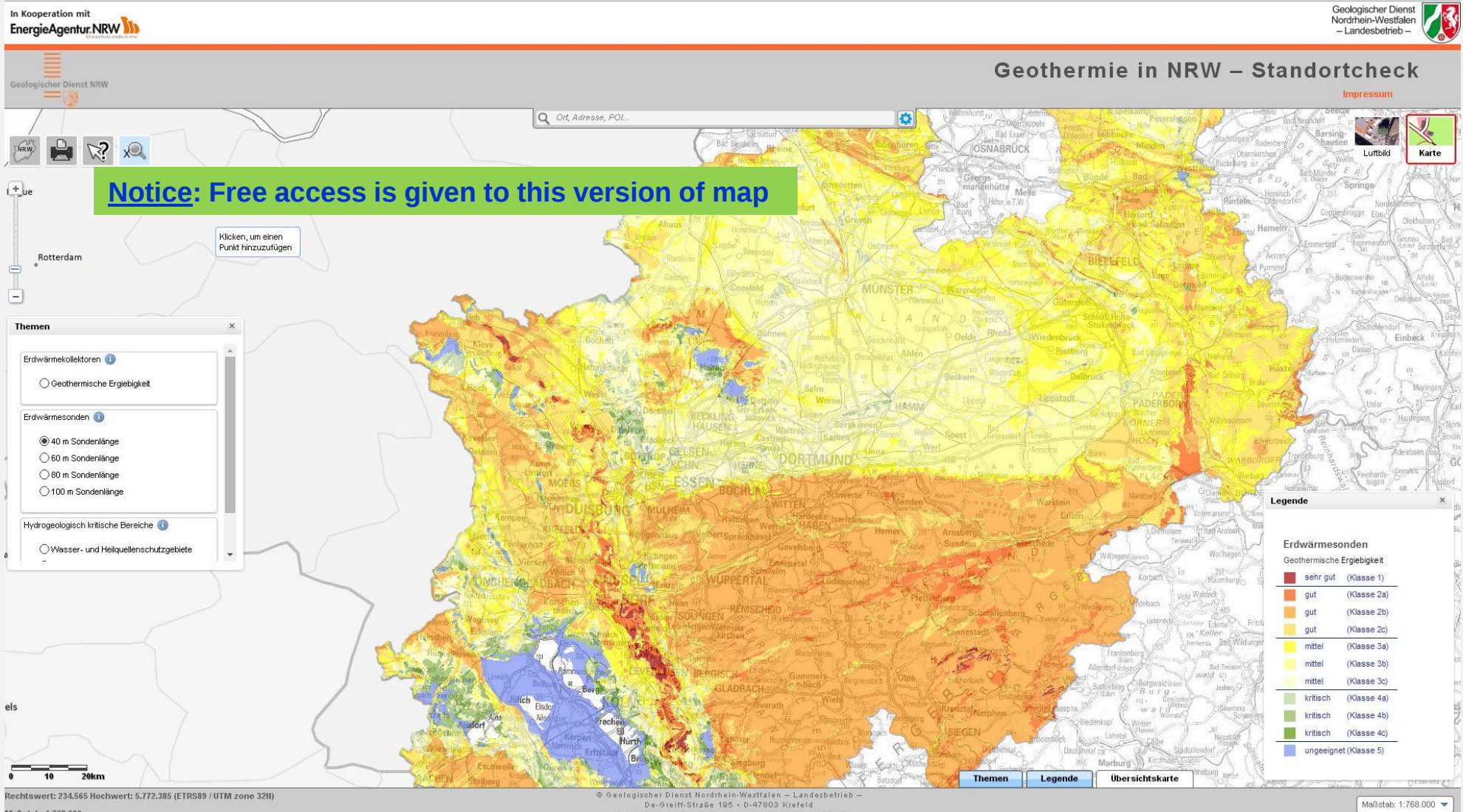
Notice: This version of map is available for a fee

Depth: 0-40 m

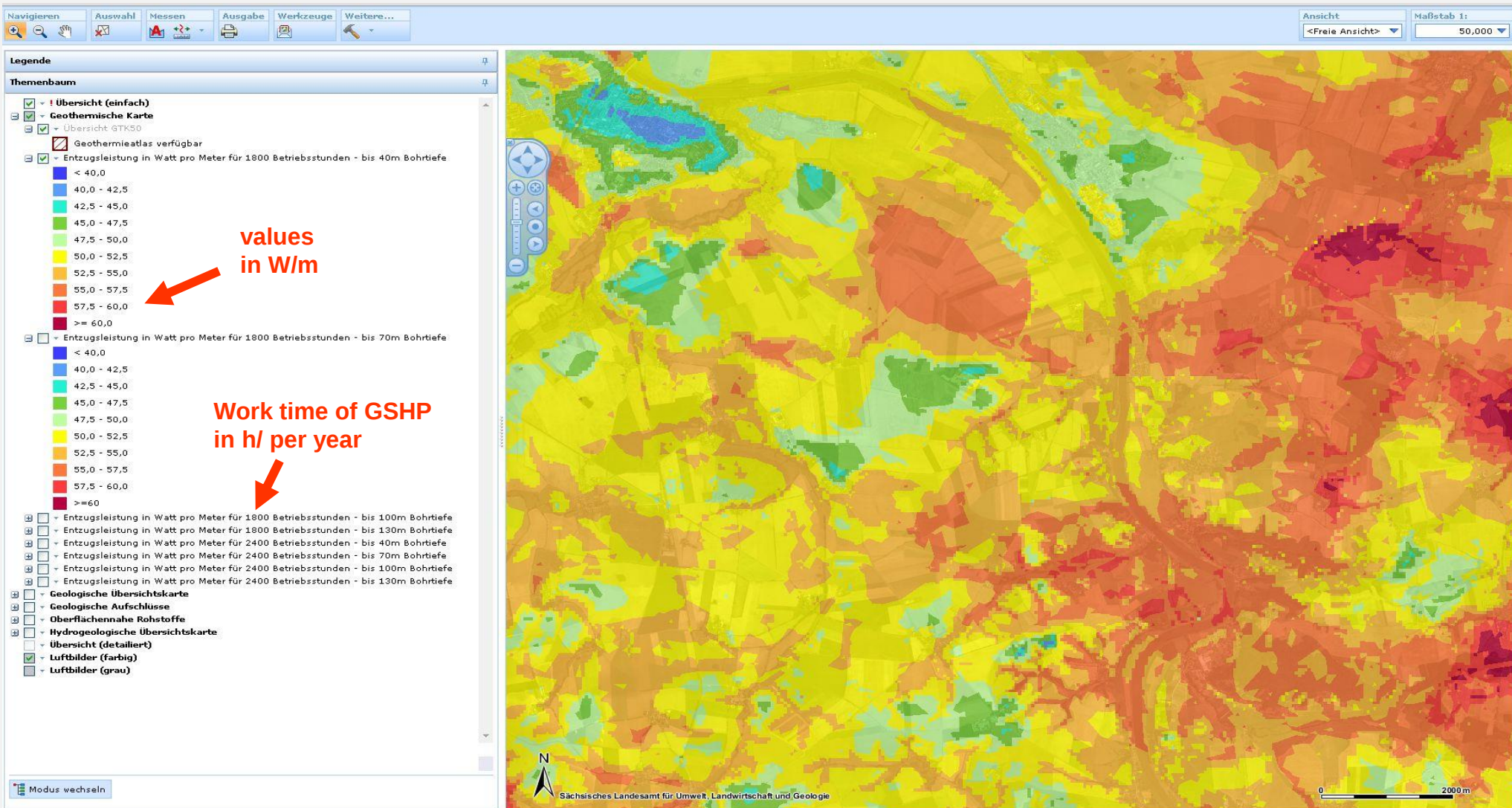
Work time of GSHP: 2400 h/a

Values in kilowatt-hour
 kWh/m

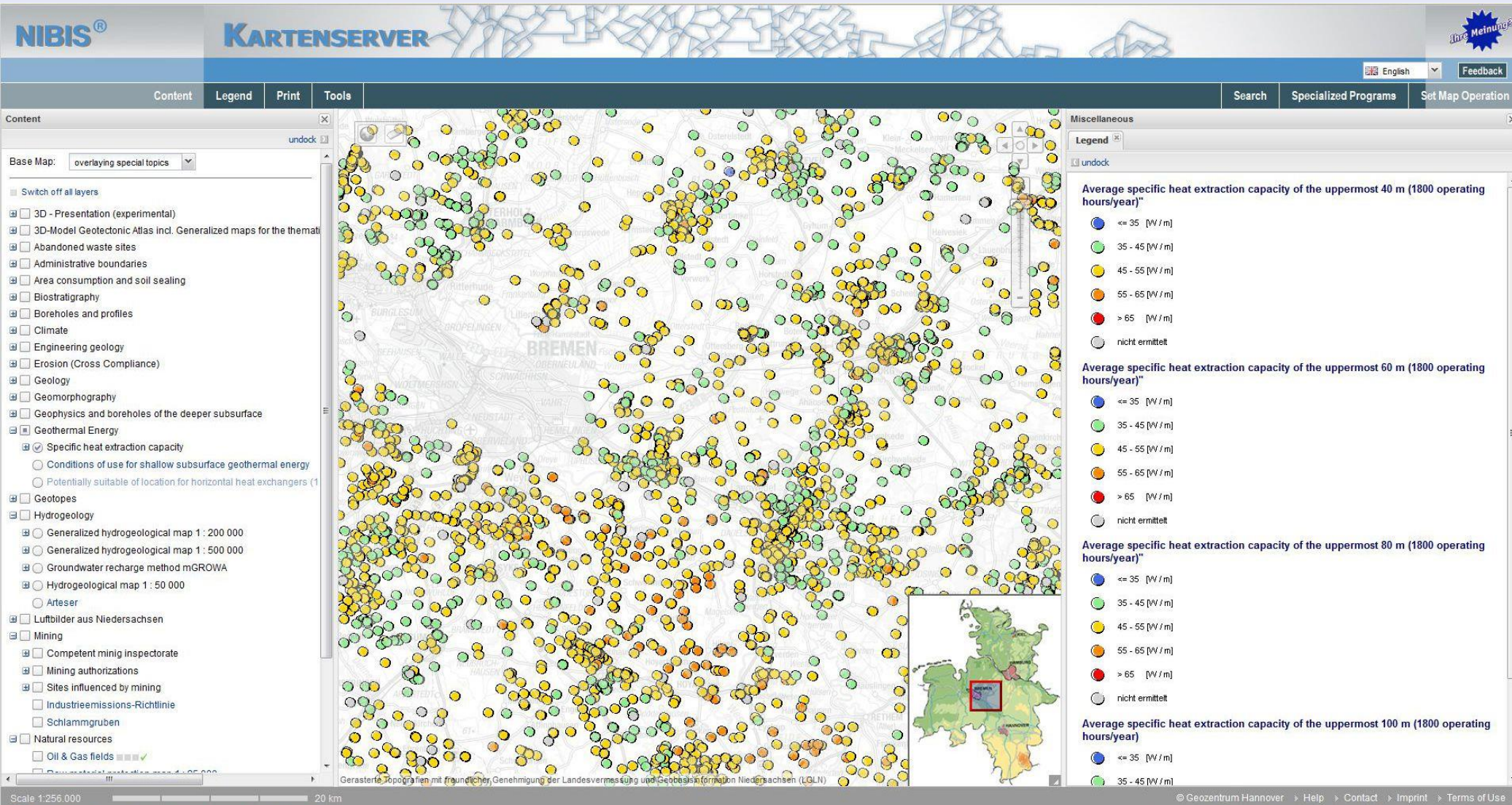
Land Rhine-North Westfalia: Map of site assessment for installation of GSHP based on thermal properties of rocks shown as classes (not real values)



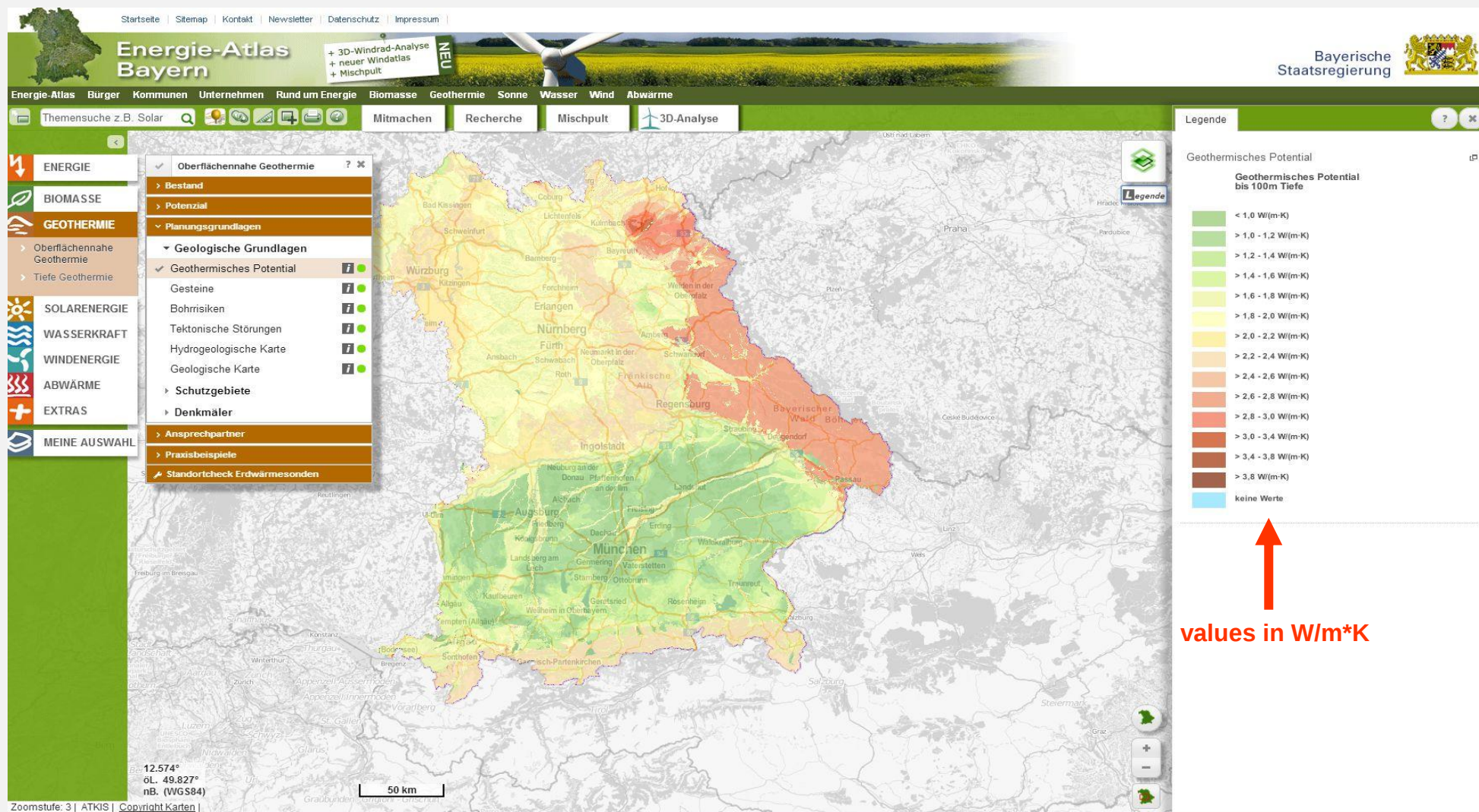
Land Saxony: map of geothermal potential based on geological 3D model and calculated values on heat extraction rate [W/m], for depths of 40, 70, 100 and 130m; 1800 and 2400 h per year of GSHP work time



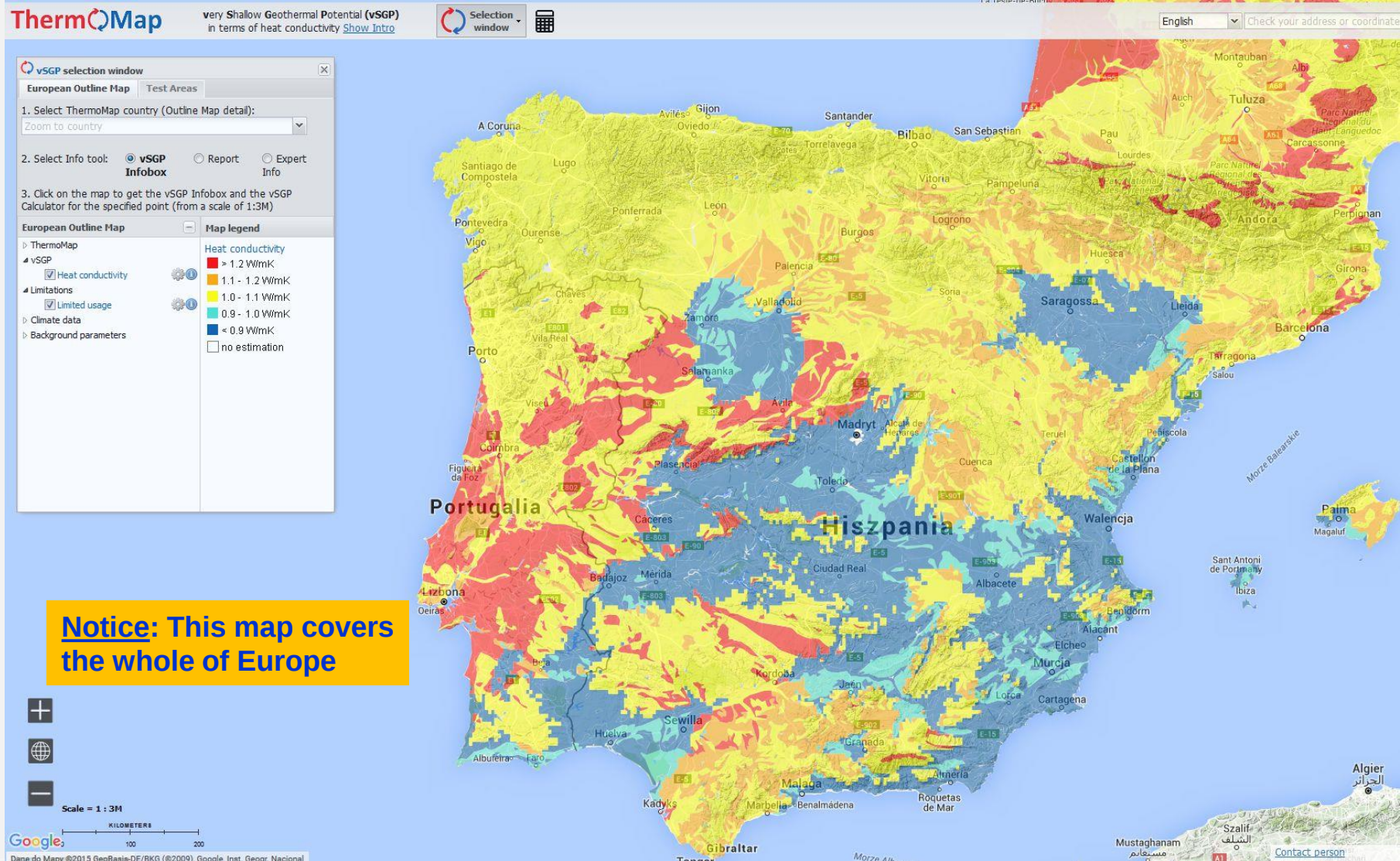
Land Lower Saxony: map of geothermal potential based on geological data from boreholes and calculated values on heat extraction rate [W/m], for depths of 40, 60, 80 and 100m; 1800 h per year of GSHP work time



Land Bavaria: map of geothermal potential based on geological 3D model and calculated values of thermal conductivity of rocks [$\text{W/m}\cdot\text{K}$], for depth of 100m



ThermoMap project: map for estimation of the very Shallow Geothermal Potential (vSGP) in terms of heat conductivity [$\text{W/m}\cdot\text{K}$], of unconsolidated underground up to 10m



Notice: This map covers the whole of Europe

Qualitative geothermal maps – Project Transgeotherm



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Title: TransGeoTherm – Geothermal energy for transboundary development of the Neisse region. Pilot project

Co-operation of two partners:

Lead partner: Polish Geological Institute – National Research Institute, Lower Silesian Branch:



Wiesław Kozdrój, Maciej Kłonowski, Adam Mydlowski, Urszula Domańska, Małgorzata Ziółkowska-Kozdrój, Janusz Badura, Bogusław Przybylski, Dorota Russ, Karol Zawistowski, Paweł Karamański, Dariusz Czerski

Project partner: Sächsisches Landesamt für Umwelt, Landwirtschaft und Geologie, Abteilung Geologie:

LANDESAMT FÜR UMWELT,
LANDWIRTSCHAFT
UND GEOLOGIE



Ottomar Krentz, Karina Hofmann, Peter Riedel, Silke Reinhardt, Mario Breitschneider

Project is co-financed from the EU financial sources within the framework of the Operational Programme for Transboundary Co-operation Poland-Saxony 2007-2013

• project life time: **01.10.2012 – 31.12.2014**

Contact: transgeotherm@pgi.gov.pl

www.transgeotherm.eu

Project TransGeoTherm covers area of ca 1 000 km²



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How the geothermal maps are produced?

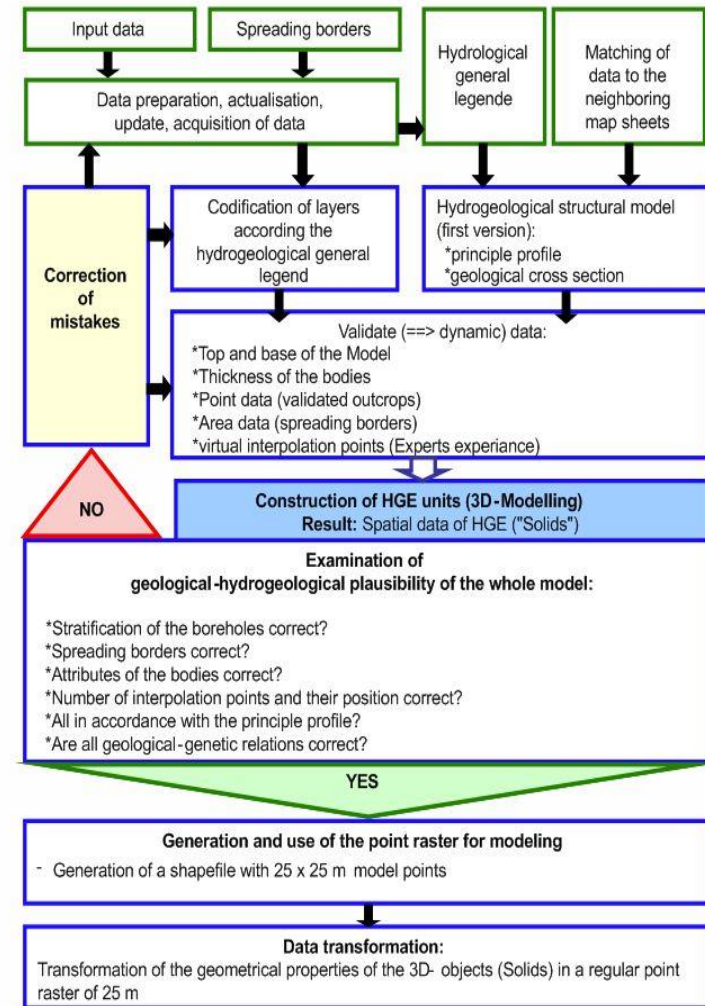
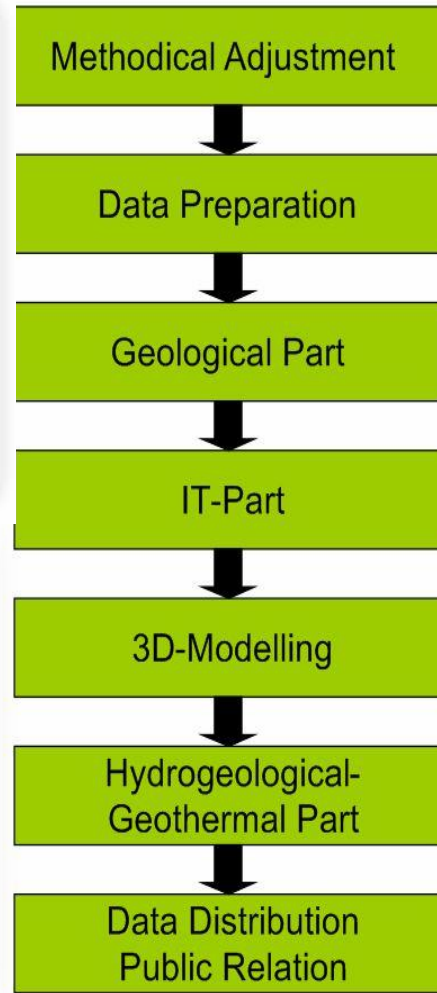
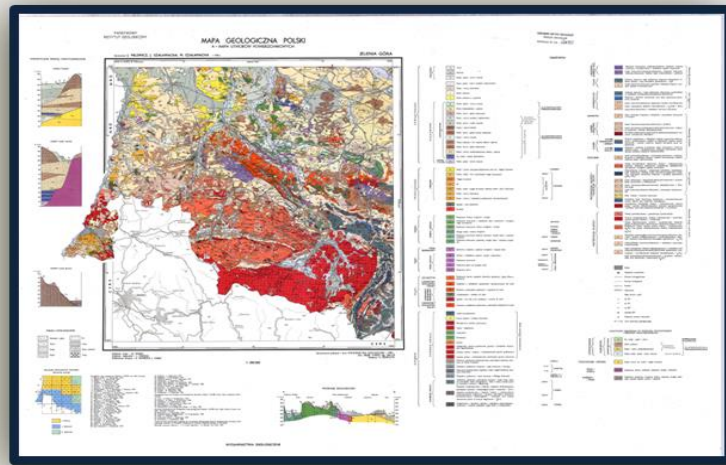
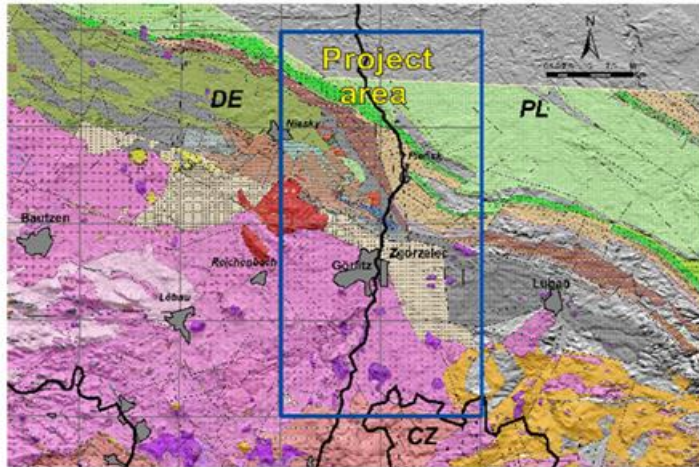


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Geothermal maps of the project TransGeoTherm are based on innovative and advanced technology of analysis and interpretation of geological and hydrogeological data, thermal properties of rocks and preparation of a 3D numerical model.

All data are analysed, combined and interpreted following specifically established methodology

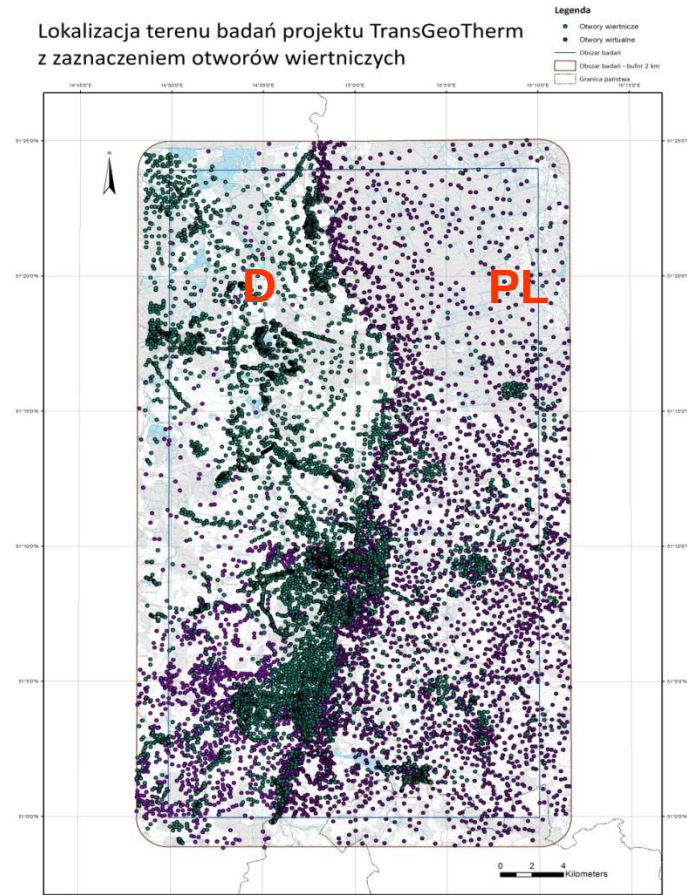


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The core of the data base consists of : selected **5146** borehole logs + **5168** virtual boreholes, with lithological profiles grouped into 75 hydrogeological – geothermal (HGE) units

Lokalizacja terenu badań projektu TransGeoTherm z zaznaczeniem otworów wiertniczych



Legende

Kánozoikum

Quartár

Holozán

Weichsel-Kaltzeit

Saale-Kaltzeit

Elster bis Saale-Kaltzeit

Elster-Kaltzeit

Tertiár Sedimente

Legende

Kánozoikum

Quartár

Holozán

Weichsel-Kaltzeit

Saale-Kaltzeit

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Quartár

Holozán

Weichsel-Kaltzeit

Saale-Kaltzeit

Elster bis Saale-Kaltzeit

Elster-Kaltzeit

Tertiár Sedimente

Legende

Kánozoikum

Quartár

Holozán

Weichsel-Kaltzeit

Saale-Kaltzeit

Elster bis Saale-Kaltzeit

Elster-Kaltzeit

Tertiár Sedimente

Legende

- 23232 piaski, miejscami węgle brunatne (TT4a)
- 23234 muki, miejscami piaski drobnziarniste (TT4a)
- 23232 piaski, muki, iły (TT4a)
- 23239 muki, iły, miejscami węgle brunatne (TT4a)
- 23234 muki, iły, węgle brunatne, miejscami piaski (TT4a)
- 23238 piaski, miejscami węgle brunatne, muki, iły (TT4a)
- 23222 piaski (Cottbus-Fm. (TT3))
- 22012 Berzdorf: węgle brunatne, muki
- 22014 Berzdorf: muki, piaski lub iły z węgle brunatne (złota 5-13)
- 22017 Berzdorf: węgle brunatne, iły, muki (złota 1-1,5, 2-4)
- 23012 Berzdorf: iły, muki, piaski, zwiły
- 22010 Radomierz: trzyczorząd ponad złotą, iły i muki szaro-zielone, lokalnie węgle brunatne
- 22011 Radomierz: trzyczorząd z złotą, węgle brunatne z przewarstwianiami ił i mułami
- 22018 Radomierz: trzyczorząd pod złotą, iły, muki, piaski, zwiły
- 29950 regolity, kady

Tertiár Vulkanite

Mesozoikum

Kreide

- 95028 piaskowce, mułowce i łowce (st) - formacja z Czernej + Węglina
- 95027 łowce - mułowce (st) -
- 95026 mułowce margliste (cn)
- 95025 piaskowce (cn)
- 95024 piaskowce (cn) - ogniwu z Żerkowic ogniwu z Dobry
- 95023 margle (cn) formacja z Rakowic - upper part
- 95022 margle (t) formacja z Rakowic - lower part
- 95021 piaskowce (t) - Ogniwu z Chmielna
- 95020 wapnie (t) - ogniwu z Przewozu
- 95019 margle (c)
- 95018 piaskowce (c) - ogniwu z Wilkowa
- 95017 łowce i ewaporaty (T1.3)
- 95016 piaskowce i zlepieńce (T1-1.2)

Trias

Jungpaläozoikum

Perm

- 95519 ewaporaty (P2)
- 95518 zlepieńce i piaskowce (P1 i C2-P1)
- 95521 piaskowce i zlepieńce (P1)

Variskische Magmatite

- 96003 monogranity biotytowe

Karbon

Oberkarbon

- 96019 wylewne skały zasadowe
- 96020 wylewne skały kwaśne
- 96027 zlepieńce i łowce (C2)

Altpaläozoikum

Unterkarbon

- 96012 fylity (C1)
- 96028 szarogłazy i piaskowce
- 96026 szarogłazy i łowce (C1)

Devon

- 96412 łupki, kwarcyty i tufy (D)
- 96413 szarogłazy i łupki (D)
- 96414 diabazy i tufy (D)
- 96414 łupki i czerty (D)
- 96403 piaskowce i kwarcyty (D)

Silur

- 96553 czerty i łupki (S)

Ordovizium bis Silur

- 97008 łupki, kwarcyty i diabazy (O-D)

Kambrium-Ordovizium

- 97816 granity i monogranity biotytowe (CO)
- 97812 ortognejsy (CO)
- 97708 monogranity - granodiority biotytowe (CO)
- 97264 dolomity, wapniene i łupki (C)
- 97265 zasadowe skały wylewne (C)

Proterozoikum bis Paläozoikum

- 97707 granodiority biotytowe (PR)
- 97711 zmetamorfizowane kontaktowo szarogłazy i łupki (chromitowy)

Proterozoikum

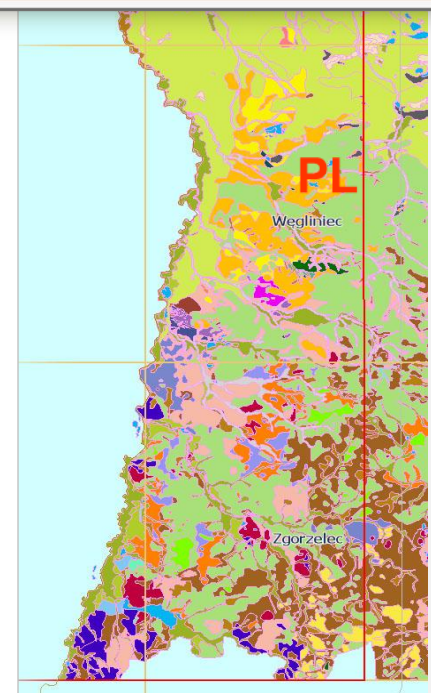
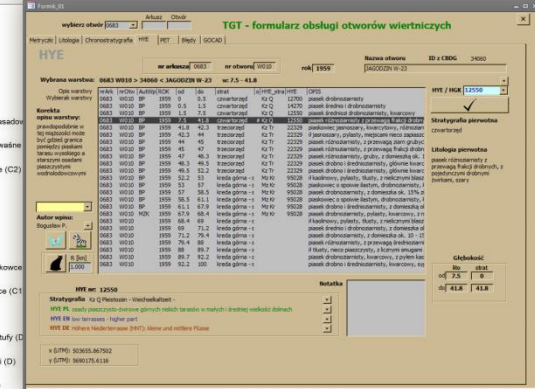
- 97709 szarogłazy i łupki (PR)

Gänge, Alter unterschiedlich

- 96010 żyły rżółtawe
- 96008 żyły diorytowe
- 96012 żyły lamprofrowe
- 97809 żyły kwarcowe

Tektonische Störungen (sicher/unsicher)

- Hauptstörung 1. Ordnung
- Nebenstörung 2. Ordnung



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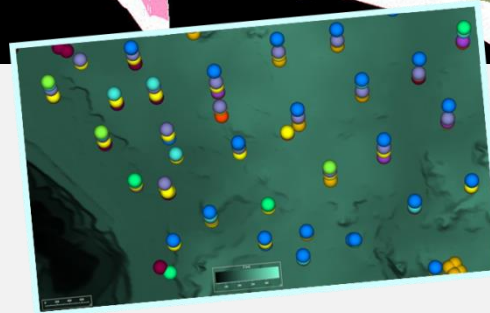
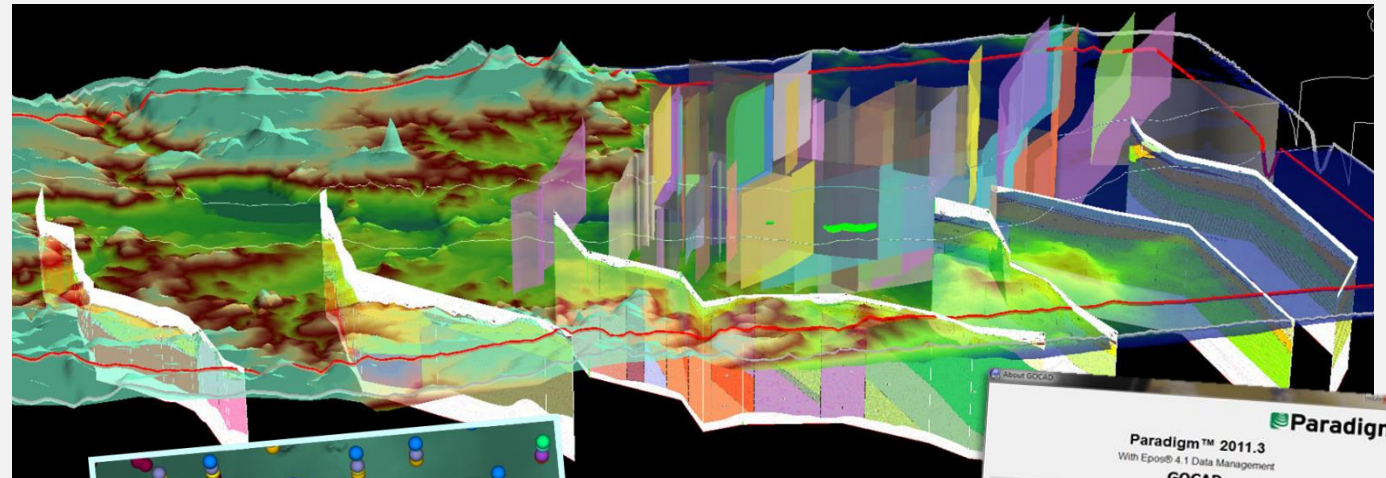
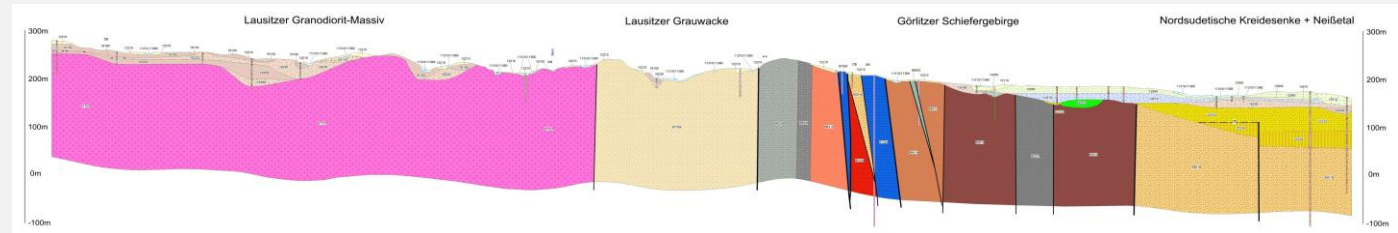
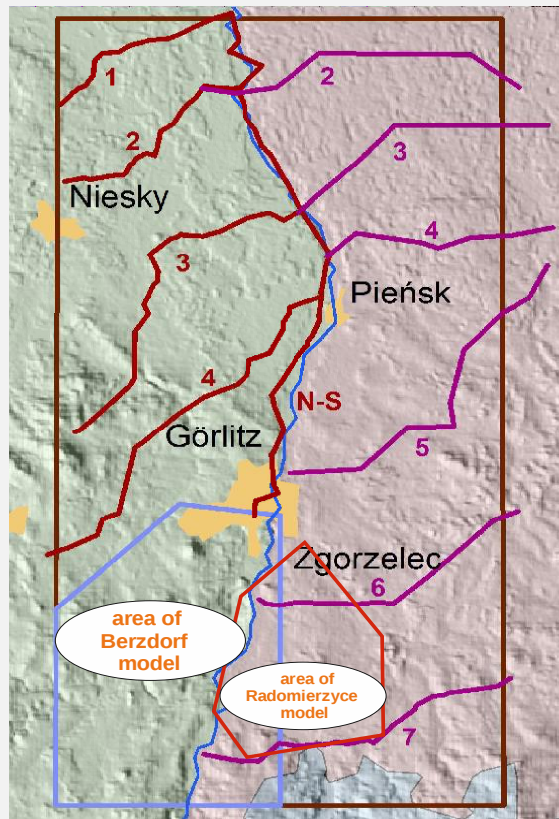


trans
GEOTHERM



Unia Europejska. Europejski Fundusz Rozwoju Regionalnego. Inwestujemy w waszą przyszłość/
Europäische Union. Europäischer Fonds für regionale Entwicklung. Investition in Ihre Zukunft

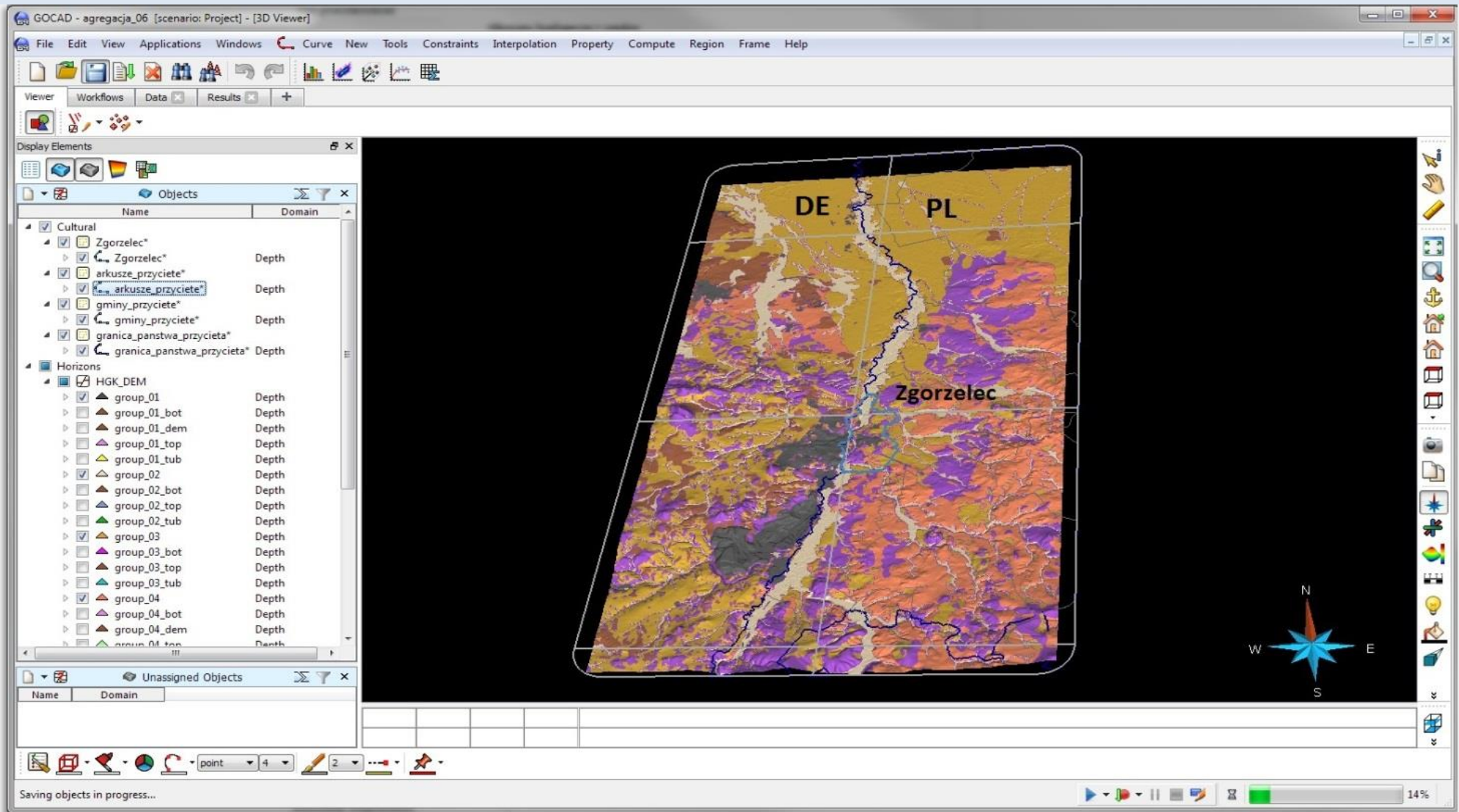
Boreholes with codified lithologies (in accordance with HGE list) and several geological cross-sections are used as a leading reference to construct a 3D numerical model processed by the GOCAD software, down to 200 meters depth (locally down to 340 m)



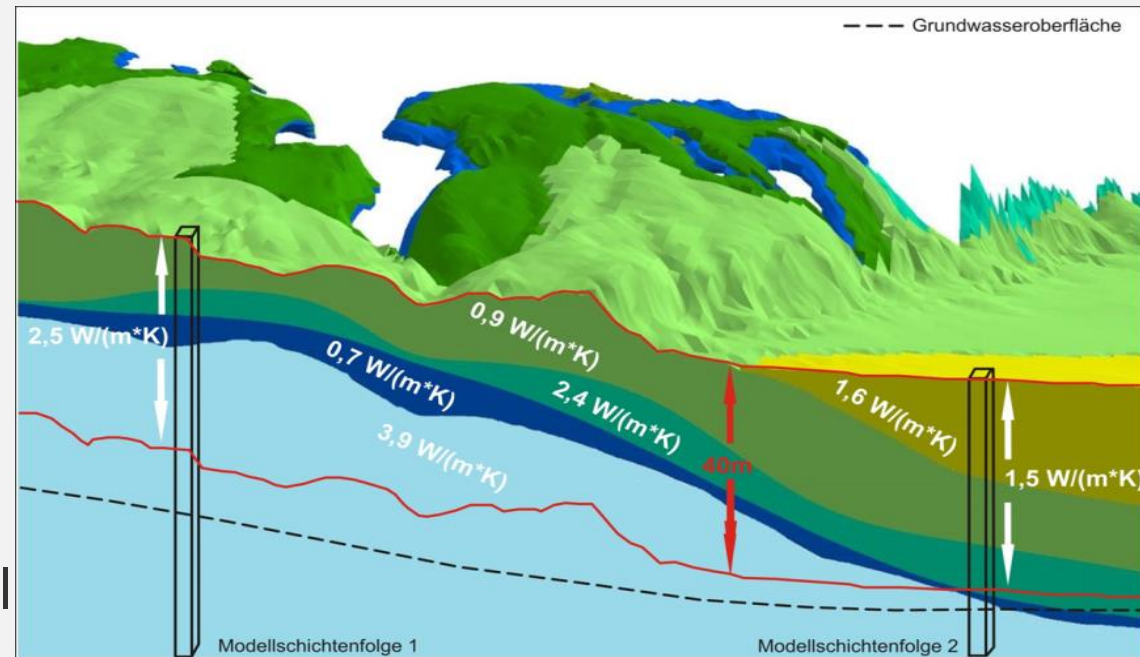
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At the end of the Gocad modelling procedure the raster data sets of the top, bottom and thickness of every HGE unit is calculated from the 3D geological model with a grid-size of 25 by 25 metres.



Based on the geothermal properties of the rocks and their groundwater content a specific value of geothermal conductivity (λ) is allocated to each lithological layer (=petrographic rock type) at every borehole



Example of borehole log divided and coded into different HGK bodies

assignment λ_{dry} , $\lambda_{H_2O\text{ saturated}}$ depending on petrography
depth-weighted mean λ_{dry} , $\lambda_{H_2O\text{ saturated}}$ on each borehole within hydrogeol. spread (solid)

HGE 5	silt	1 m	λ_{dry} : 0,9 W/m·K	$\lambda_{H_2O\text{ sat.}}$: 1,8 W/m·K	λ_{dry} : 0,9 W/m·K	$\lambda_{H_2O\text{ sat.}}$: 1,8 W/m·K
HGE 10	sand	1,5 m	λ_{dry} : 0,4 W/m·K	$\lambda_{H_2O\text{ sat.}}$: 2,4 W/m·K	λ_{dry} : 0,4 W/m·K	$\lambda_{H_2O\text{ sat.}}$: 2,0 W/m·K
HGE 10	sand, gravelly	4 m	λ_{dry} : 0,4 W/m·K	$\lambda_{H_2O\text{ sat.}}$: 1,8 W/m·K	λ_{dry} : 0,4 W/m·K	$\lambda_{H_2O\text{ sat.}}$: 2,0 W/m·K
HGE 21	shale, weathered	1,5 m	λ_{dry} : 0,5 W/m·K	$\lambda_{H_2O\text{ sat.}}$: 1,7 W/m·K	λ_{dry} : 1,8 W/m·K	$\lambda_{H_2O\text{ sat.}}$: 2,0 W/m·K
HGE 21	shale, dense	4 m	λ_{dry} : 2,1 W/m·K	$\lambda_{H_2O\text{ sat.}}$: 2,1 W/m·K	λ_{dry} : 1,8 W/m·K	$\lambda_{H_2O\text{ sat.}}$: 2,0 W/m·K

Result: for every section of a borehole, belonging to a certain HGE unit of the 3D geological model, a depth-weighted mean λ value is calculated.

Output: two-grid datasets of thermal conductivity (for dry and H_2O saturated rocks) for every HGE unit

Calculation of geothermal grids using specially designed GIS-Extension

Berechnung IE Geothermie 3

Eingangsdaten

Auswahl einer Shapedatei nach GIS-Verschneidung (z. B. 'c:\temp\input.shp')

G:\Abt10\Projekte\Geothermie\TransGeoTherm\GIS\GTK50_KARINA\Output\output.sl

Ausgewählter Datensatz: 10 hydrogeologische Körper im Eingangsdatensatz.

Eingabewerte

Nutzungsstunden: 1800 [h]

Tiefenbereich: 100 [m u. Gelände]

Ausgabewert: ☐ P Entzug in W/m ☐ P Entzug in W für Tiefenbereich ☒ Lambda-Wert

Ausgabeverzeichnis

G:\Abt10\Projekte\Geothermie\TransGeoTherm\GIS\GTK50_KARINA\Output\

Berechnungsstatus

Zeit: 13 Sec.

Berechnung der Geothermieebene beendet !
Hinweis: Berechnung erfolgte ohne Fehler

Schliessen

select generated output_shape

select features:

- Annual operation hours of heat pump: 1800 h or 2400 h
- Depth levels: 40 m, 70 m, 100 m, 130 m

select output option

Output:

8 Maps of geothermal mean heat extraction rate [W/m] →
4 depth-intervalls x 2 annual operation hours (1800 and 2400)

4 Map of mean thermal conductivity [W/m·K] →
Lambda-distribution for 4 depth-intervalls



Results : 12 geothermal maps, including:

8 Maps of mean heat extraction rate in W/m
„public version“

for 1800 annual operation
hours of heat pump
(only for heating)

0 - 40 m

0 - 70 m

0 - 100 m

0 - 130 m

for 2400 annual operation
hours of heat pump
(heating + hot water)

0 - 40 m

0 - 70 m

0 - 100 m

0 - 130 m

**4 Map of mean thermal
conductivity in W/m·K**
“professional version”

0 - 40 m

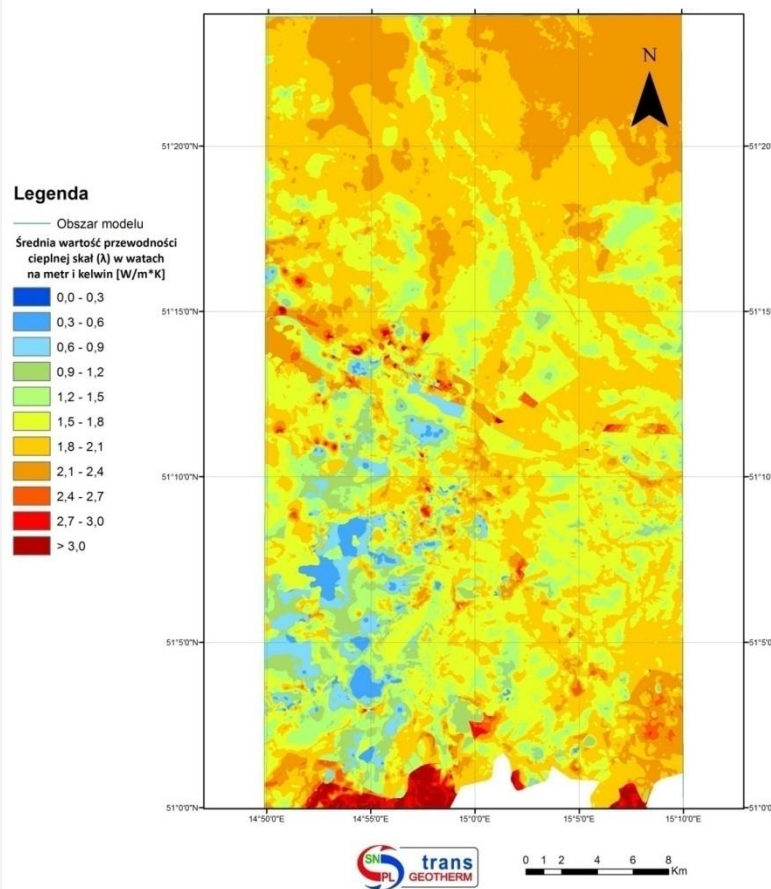
0 - 70 m

0 - 100 m

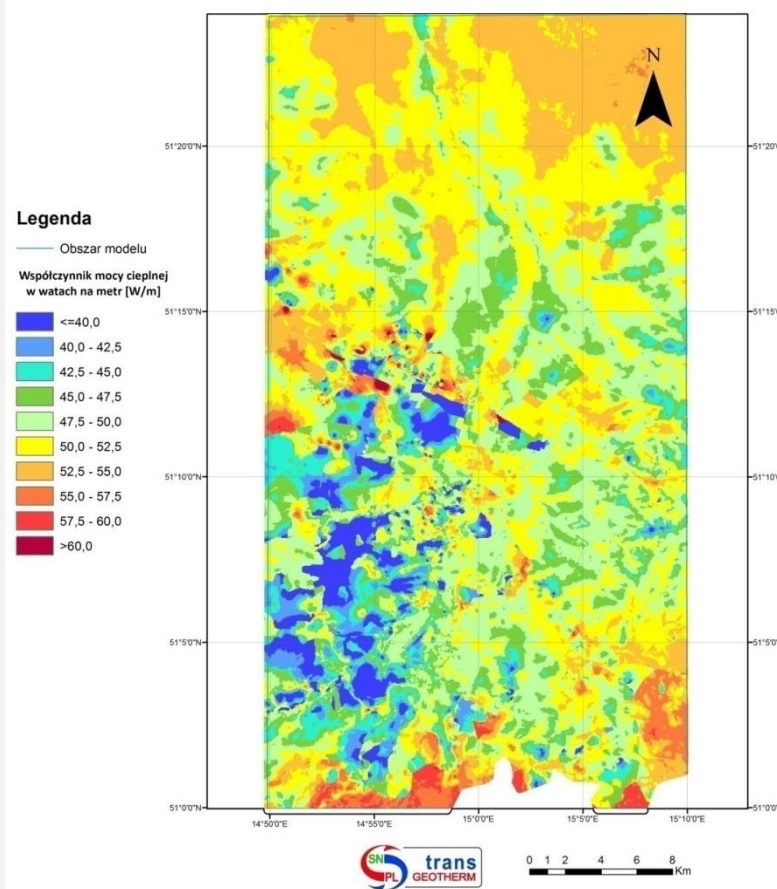
0 - 130 m

www.transgeotherm.eu

W/m*K , 0-40 m

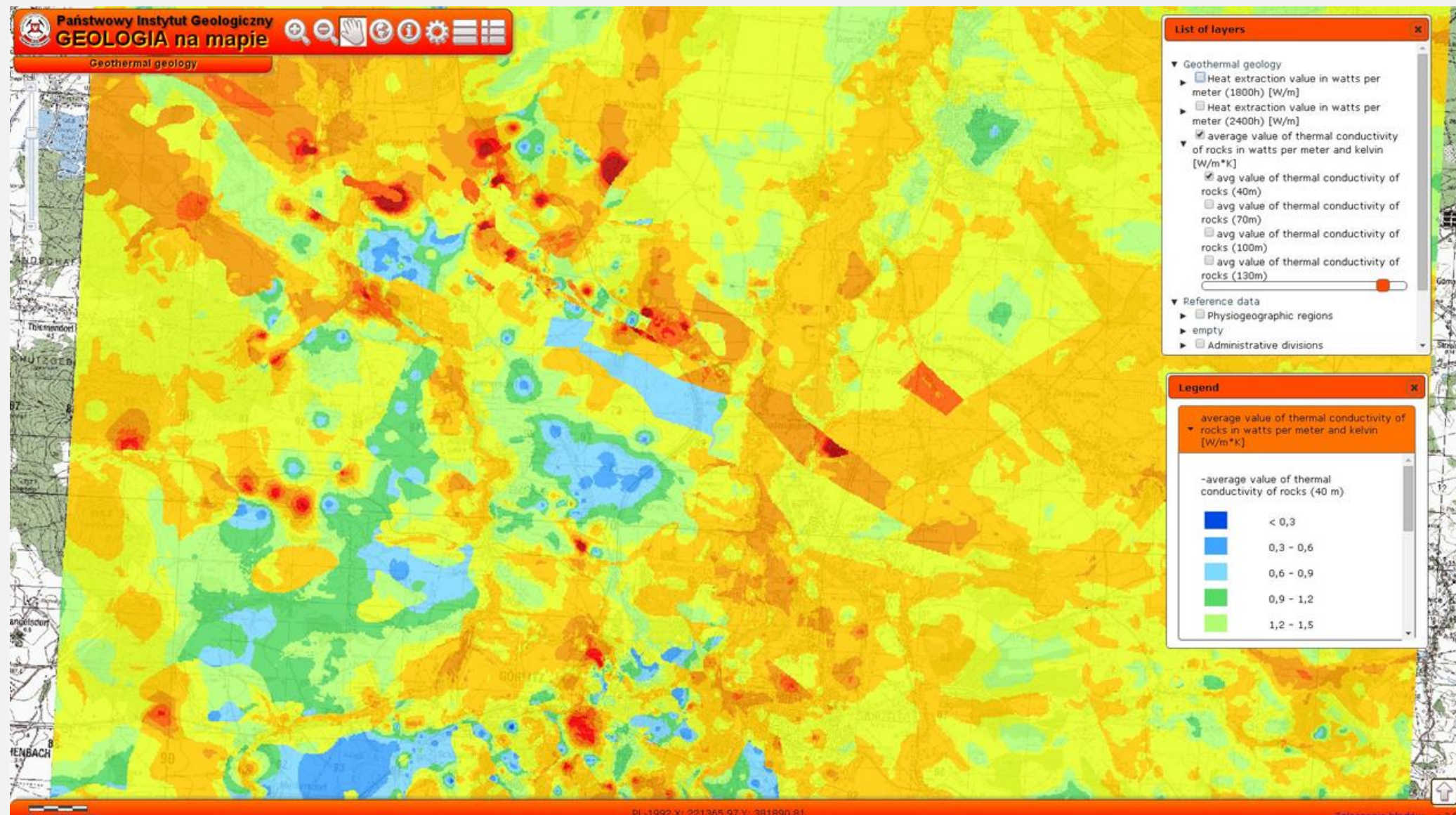


W/m , 0-40 m,
1800 h



Geothermal maps are also available on-line via internet application of PGI-NRI

www.transgeotherm.eu



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How to use geothermal maps?



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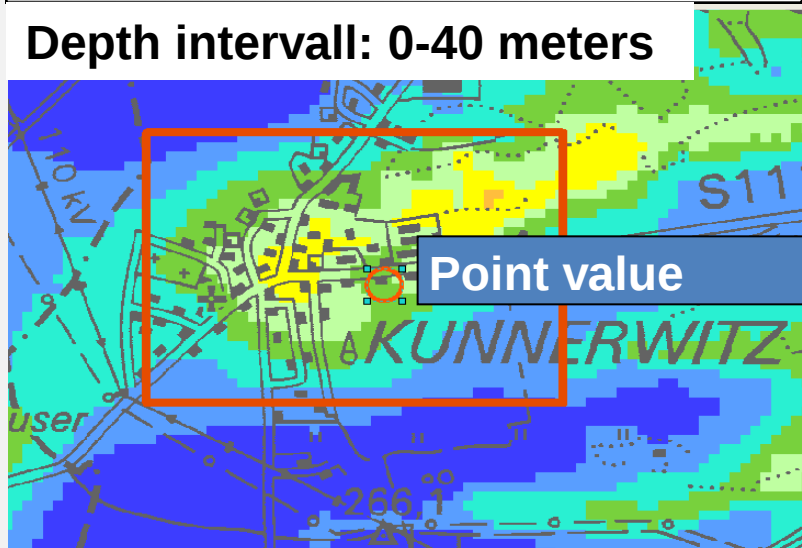
www.pgi.gov.pl

How to use geothermal maps of the “public version”

Calculation of borehole number & depths for heat pump installation

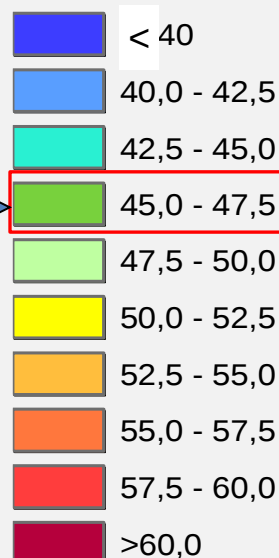
Example: one family house,
12 kW power demand,
only for heating

Depth intervall: 0-40 meters



Legend:

heat extraction in watts per meter [W/m] at a depth of **0-40 meters** and **1800 annual operation hours** of a geothermal heat pump



$$45,0 - 47,5 \times 40 \text{ m} = 1800 \dots 1900 \text{ W}$$

$$= 1,8 \dots 1,9 \text{ kW}$$

$$12 \text{ kW} \div 1,8 \text{ kW} = 6,6$$

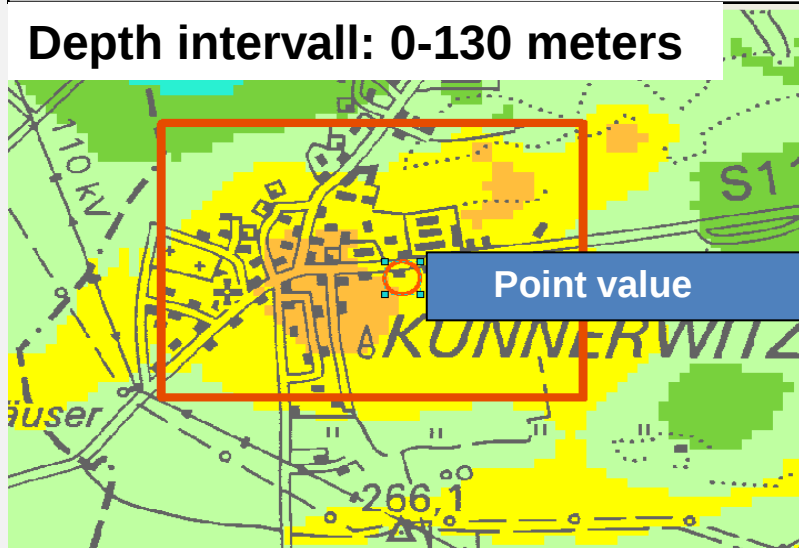
Result:
7 boreholes of 40 m deep

How to use geothermal maps of the “public version”

Calculation of borehole number & depths for heat pump installation

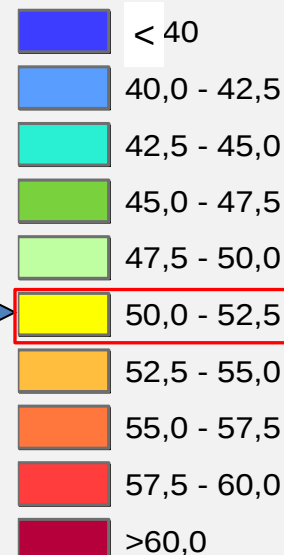
Example: one family house,
12 kW power demand,
only for heating

Depth intervall: 0-130 meters



Legend:

heat extraction in watts per meter [W/m] at a depth of **0-40 meters** and **1800 annual operation hours** of a geothermal heat pump



$$\times \quad 130 \text{ m} = 6500 \dots 6825 \text{ W}$$



$$6,5 \dots 6,8 \text{ kW}$$

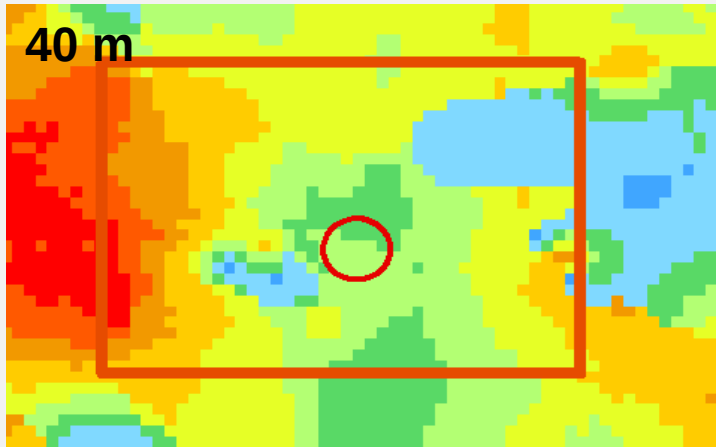


$$12 \text{ kW} \div 6,5 \text{ kW} = 1,8$$

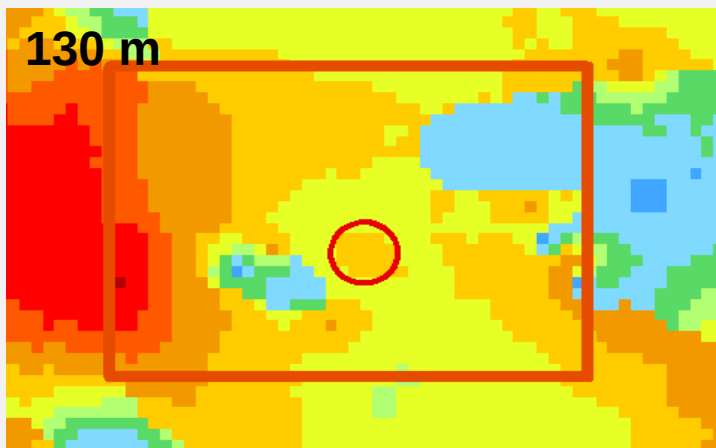


Result:
2 boreholes of 130 m deep

How to use geothermal maps of the “professional version”

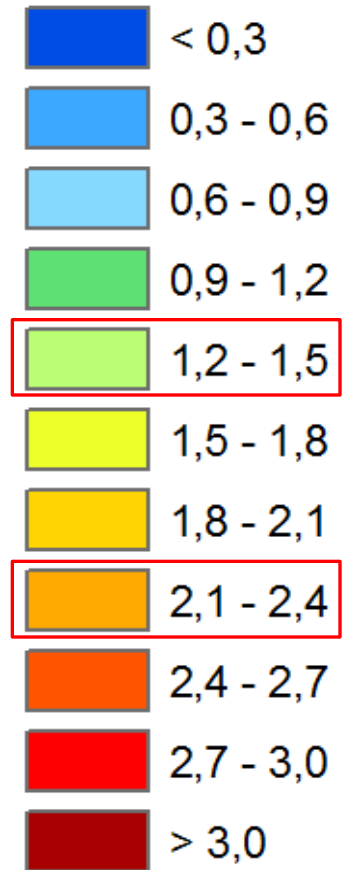


Legend:
mean thermal conductivity
in W/m·K
for depth intervall **0-40 m**



Legend:
mean thermal conductivity
in W/m·K
for depth intervall **0-130 m**

λ w W/m·K



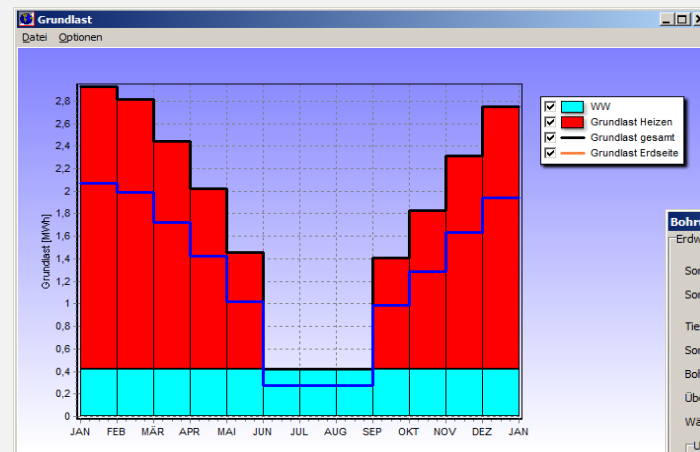
How to use geothermal maps of the “professional version”

Variant: planned borehole of 130 m depth → with mean value of $\lambda = 2,1 \text{ W/m}\cdot\text{K}$

Correct valuation of ground heat pump installation for 25 years of exploitation using **Earth Energy Designer EED software**

Other data are necessary !!! :

- Technical specification of the heat pump
- Monthly energy power demand
- Technical parameters of heat pump exchanger and plumbing materials of borehole
- Location data:
 - Mean annual temperature
 - Thermal capacity of rocks
 - **Thermal conductivity λ of basement rocks**



Thank you very much for your attention



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