GeoPLASMA-CE: Assessment of methods for 3D-modelling

Deliverable D.T2.2.1: Synopsis of geological 3D-modelling methods

03 2017

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Content

Glossary

	description
geothermal energy	Energy stored below the surface of the solid earth in the form of heat
Shallow geothermal use	The use of geothermal energy until a depth of 400 m
geothermal potential	The useful accessible resource – that part of geothermal energy of a given area that could be extracted economically and legally at some specified time in the future
risk and land-use conflicts	direct or indirect negative impact on the environment which geothermal exploitation affects to the compartments (water, soil, air, nature) and on other land uses nearby
3D structural model	describes the geometry, spatial distribution and neighborhood relationship of geological units in the modelling domain
suitability	The possibility to use shallow geothermal energy by a specific method
parameter model	Assigns physical or chemical parameters to the geological units specified in the 3D structural model. It can be used for calculations or predictions.
map	is a projection of a high-dimensional object on a plane. Usually, it is a scaled, simplified and generalized model of the earth.
thematic geothermal mapping	Calculation and visualisation of geothermal potential by specific thematic output parameters (e.g. thermal conductivity, extraction rates)
thematic conflict mapping	Calculation and visualisation of land-use conflicts and risk areas due to geothermal utilisation (e.g. traffic light maps, specific conflict layers)
metadata	is data that provides information about data which makes working with the data easier. Structural metadata are used by the computer, guide metadata help humans to find specific information about the data

1. Introduction

The aim of the GeoPLASMA-CE project is to develop new management strategies for shallow geothermal use of urban and non-urban regions. The project intends to create a standardized data base and a web-based platform including the geothermal potential as well as factors of risk and land-use conflicts. The data comprises geological and structural data, petrophysical and technical parameters as well as the model data produced during different stages of the project. The geothermal potential modelling and the risk-factor validation will be based on a 3D structural model of the shallow geological subsurface which will be used to quantify the spatial distribution of physical and technical parameters and of risk factors.

To elaborate a compilation and assessment of existing methods, a literature study was conducted as first step for establishing a workflow for geothermal modelling in GeoPLASMA-CE. Information about existing methods for 3D-modelling, mapping the potential of open loop and closed loop systems as well as land-use-conflict was gathered. The applicability of the methods used in the projects for GeoPLASMA-CE was investigated in a next step. The project team created a template to summarize the most important information about the methods regarding the topics mentioned (3D-modelling, open loop and closed loop systems, land-use-conflict mapping). Summaries of all methods and lessons learned from the projects, which provide important inputs, were established for four separate reports, based on these standardized assessment sheets:

- Synopsis of geological 3D-modelling methods,
- Synopsis of geothermal mapping methods - open loop systems,
- Synopsis of geothermal mapping methods - closed loop systems,
- Synopsis of mapping methods of land-use conflicts and environmental impact assessment.

All assessment sheets are added in **Annex 1** for further information. The publications concerning the analysed projects were collected and are available for further research and use in the database "knowledge repository".

This process generated important knowledge about how to develop workflows of geothermal mapping for GeoPLASMA-CE, which will be accomplished within the next steps.

The delivered four reports and the knowledge repository will be available online at the project's website (http://www.interreg-central.eu/Content.Node/GeoPLASMA-CE.html).

2. General workflow for geothermal mapping based on a 3D model

In general, all workflows for mapping the geothermal potential have to follow one scheme **(Figure 1)**:

The modelling has to include geometric and physical data, this data has to be interpreted and prepared according to the projects' objectives. Then, the spatial distribution of the physical parameters has to be modelled. This includes the major step of generating a structural model of the subsurface.

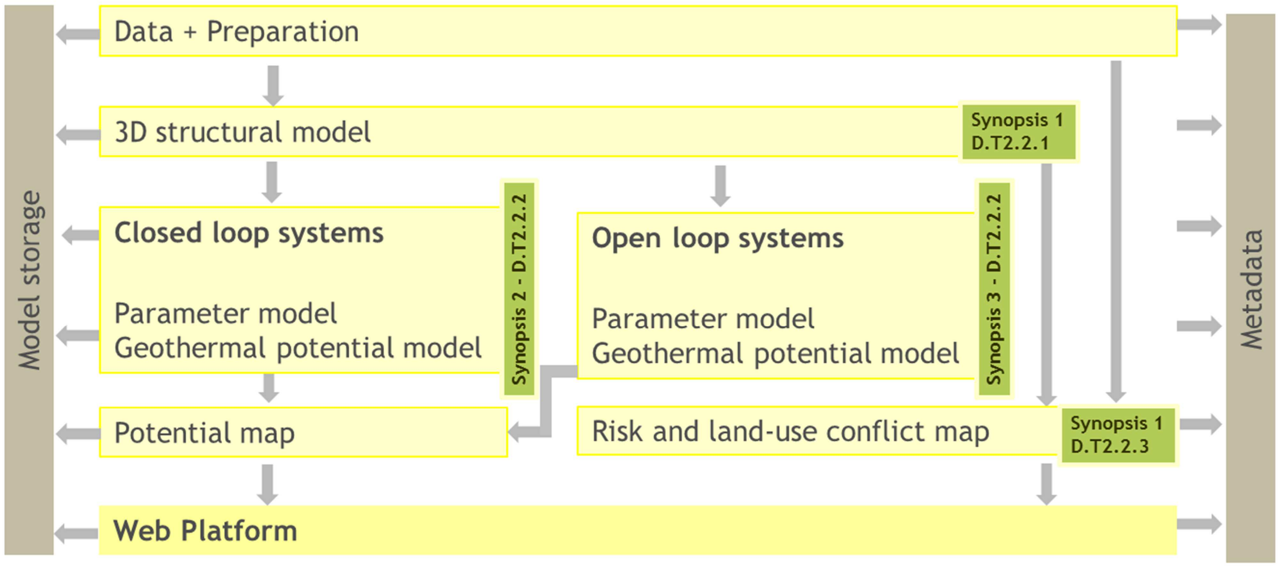


Figure 1: Workflow for modelling the geothermal potential of a region.

The first step of all is to build a geological 3D model related to geothermal and hydrogeological issues as a basis for the thematic geothermal mapping and land-use conflict mapping.

The structural model has to be parameterized with the physical parameters needed to solve the equations describing the geothermal potential. Then, the geothermal potential is calculated. The geothermal potentials for open loop and closed loop systems will be determined separately for GeoPLASMA-CE. The outputs of the potential modelling are divided into suitability classes and visualized within a next step, in order to ensure an easy handling for the stakeholders. This result has to be visualized for the stakeholders of the model.

For the risk and land-use conflict maps some additional information is necessary, which cannot all be extracted from the structural model, i.e. the location of groundwater protection zones or natural reserves. This information has to be included into the steps of thematic map production. If the thematic maps shall be displayed on a screen, a conversion of the 3D modelling results into 2D potential maps is necessary. The maps can be displayed on a web-platform with specific visualization and querying functions. Since all primary and modelling data has to be stored, it is important to develop an efficient and clear scheme for storage of data and metadata.

3. 3D structural and geometrical modelling

3.1. Research of existing 3D modelling methods

3D-geomodelling was introduced by geological surveys and other administrative institutions as an experimental complement to digital maps, but 3D models are increasingly replacing maps and cross-sections and are being established as standard communicational method in geology. Many European countries have started to document their subsurface in 3D models. The 3D models are used for resource management, hydrogeology, engineering geology and geothermal calculations.

The following publications on regional 3D modelling concepts in Europe were collected and screened in preparation of the GeoPLASMA-CE project:

- GeotIS (German geothermal information system Rep. ID 25),
- NL 3D and GeoTop (Netherlands state model, Rep. ID 23),

- TUNB (deep underground of North German Basin, Rep. ID 29),
- UK3D state model (Rep. ID 3),
- Geomol (alpine molasses, Rep. ID 24),
- ISONG (information system on shallow geothermal energy in Baden-Württemberg, Rep. ID 26),
- TransGeoTherm (Polish-German border, Rep. ID 2),
- Markovec and Karavanke tunnel (Slovenia, Rep. ID 27),
- Influins (Thuringian basin, Rep. ID 4),
- Geothermieatlas and HyK 50 (geothermal atlas and hydrogeological 3D model, Saxony, Rep. ID 28).

Some of the projects follow strict workflows and concepts, other projects are more open in order to allow a cooperation of various project partners. For GeoPLASMA-Ce, both types of projects are interesting. On one hand, we want to develop a harmonized and standardized workflow. On the other hand, we have to take into account the data, software and needs of 11 partners. 8 of the projects are especially interesting for GeoPLASMA-CE and are discussed here.

The publications about these projects were collected and are available in the "knowledge repository" for further research and intern uses. The most important information was summarized in assessment templates provided as "methodical assessments". A brief overview about the most important 3D modelling projects is given in **Table 1**.

3.2. Input data

All available geological data was used for the 3D modelling projects. Usually this data comprised geological maps, drilling and seismic data as well as outcrop information. In some regions depth-contour data were available from legacy projects (TUNB REP. ID 29, GeotIS Rep. ID 25).

The input data had to be harmonized, since the lithological description in drillings and maps may vary and reference horizons in seismic and stratigraphic data are not equal (NL3D Rep. ID 23, TUNB REP. ID 29, Geomol Rep. ID 24). Additionally, different project partners used different lithological unit classifications (TransGeoTherm Rep. ID 2, TUNB REP. ID 29, Geomol Rep. ID 24).

The first step of data harmonization in all projects was to decide, which geological objects should be modelled in general. This depends on the purpose of the project. Additionally, an agreement on the modelled level of detail had to be found for all projects. This may include an agreement on the level of detail in fault modelling (Geomol Rep. ID 24, TUNB REP. ID 29). The first result of the data harmonization in all projects was a unified lithological legend comprising all lithological units to be included in the project. This and the other agreements had to be taken as rules for interpretation of the primary data. After applying the harmonization rules, interpreted harmonized data sets were available and can be used for generating the 3D models.

Table 1: Overview over some important regional 3D modelling projects in Europe.

Project	Area	Purpose	Depth	Input data	Software	Geological objects	Modelled objects	Data structure	Workflow	Data conversion - potential	Data conversion - web	Advantages	Disadvantages
GeotIS **Rep. ID 25**	Germany: North-German Basin, Hessen, Rhein Graben	deep geothermal energy	>2000 m	seismic data, drilling data, geotectonic atlas, geological maps	Skua-Gocad	main sedimentary horizons and aquifers, salt bodies, faults	horizon bases and tops, top salt bodies, fault surfaces	triangulated surfaces	modelling of independent surfaces, check for horizon crossings	voxet	2D grid	multiple z-values can be modelled	modelled objects have to be converted for geothermal modelling
NL3D GeoTop **Rep. ID 23**	Netherlands state model	state model,hydro-geology, georisks	50 m	drillings, geological maps, hydraulical data	Petrel, Isatis	stratigraphic horizons, lithological bodies	horizon bases, volumetric bodies	2D grid, voxet	model horizon bases with 2D grid and generate a voxet between two 2D grid levels	none	none	bodies can be directly parameterized	stair-case body boundaries
TUNB REP. ID 29	Germany: North German states	state model,resource potential	>2000 m	seismic data, drilling data, geotectonic atlas	Skua-Gocad	sedimentary horizons, salt bodies, faults	base and top horizons, top salt bodies, fault surfaces	triangulated surfaces	various workflows used (i.e. Skua structure and stratigraphy)	none	none	flexible workflow for many partners	a lot of communication and data exchange along the borders
UK3D REP. ID 3	Great Britan	state model, hydrogeologiy, engineering	>1000 m	geological maps, drilling data, seismic data	GSI3D	sedimentary horizons, metamorphic lithological boundaries, fault network	horizon tops and bases, faults	triangulated surfaces	net of cross-sections, bilinear interpolation between the cross-sections	voxet	not known	easy workflow	folded structures cannot be modelled
Geomol Rep. ID 24	Alpine space: France, Switzerland, Germany (BW, By), Austria, Slovenia, Italia	resource and geothermal potential	not known	geological maps, drilling data, seismic data	3D Geo-modeller, move, gocad, Skua, GST	main stratigraphic horizons, fault network	horizon bases and tops, faut surfaces	triangulated surfaces	various workflows used (i.e. Skua structure and stratigraphy)	yes - but not published	none	very flexible	modelling results are not directly comparable
ISONG REP. ID 26	Germany: Baden-Württemberg	shallow geothermal potential	200 m	geological maps, drilling data, seismic data	Skua-Gocad	main stratigraphic horizons, fault network	horizon base, unit thickness, fault surfaces	triangulated surfaces	generate a tetrahedral mesh from thickness data, extract the next horizon base from the base of the tetrahedral mesh	2D grid	not known	No horizon crossings are possible	No horizon crossings are possible
TransGeoTherm Rep. ID 2	Germany - Poland: Neisse region	shallow geothermal potential	340 m	geological maps, drilling data	Skua-Gocad	main stratigraphic horizons	horizon top, horizon base, vertical side boundaries for units, unit thickness	triangulated surfaces	generate independent triangulated surfaces , remove horizon crossings	2D grid	2D grid	all modelled boundaries can unequivocally be assigned to one geological body	vertical unit boundaries
Markovec and Karavanke tunnel Rep. ID 27	Slovenia	engineering geological 3D model	approx. 1000 m	geological maps, drilling data, outcrop data, remote sensing data	Leopfrog	main stratigraphic and metamorphic units, fault network	bodies	continuous functions, boolean bodies, triangulated surfaces	data from tunnel survey directly included into the 3D model, boundaries calculated with implicit approach, boolean bodies are constructed according to age + truncation relationship	none	none	consistent body model, tunnel included	
Influins Rep. ID 4	Thuriniga	state model, hydrogeology + deep geothermal	>1500 m	geological maps, drilling data, seismic data	Skua-Gocad	main stratigraphic horizons, fault network	horizon tops, fault surfaces	2D grid, triangulated surfaces	Skua structure and stratigraphy workflow	not known	none	consistent unit thicknesses along outcroping units	
Geothermie atlas, HyK50 **Rep. ID 28**	Saxony	hydrogeo-logical model	200m	geological maps, drilling data	Skua-Gocad, ArcGIS	main hydro-geothermal units	full boundary surface, 2D-grid-Sgrid-Vector format	2Dgrid with thickness information	generate independent triangulated surfaces , remove horizon crossings	2D grid -Sgrid -Vector format	none	topological relation of surfaces and bodies is clear	very specific data structure

A minimum number of data is necessary to model a certain level of detail, which has also to be in agreement with the size of the modelling domain, in order to avoid, that the 3D model becomes too big for subsequent calculations performed on it. Since different modelling purposes may require different levels of detail, some of the 3D modelling projects provide concepts how to combine models with different resolutions. The projects NL3D and Geotop Rep. ID 23 provided two independent models with different cell size and stratigraphic resolution, which can be used for different purposes. The Geomol Rep. ID 24 project worked with two levels of detail, a fine one for the shallow part of the model and a coarse one for the deep part of the model. Both model parts are separated along one major stratigraphic horizon. UK3D REP. ID 3 and ISONG REP. ID 26 first generated a coarse model with the major stratigraphic boundaries. Later, the stratigraphic units were modelled more in detail, such that the major boundaries which comprise the coarse model are also included into the detailed model.

After applying the harmonization rules, interpreted harmonized data sets were available which can be used for generating the 3D models.

Data harmonization is especially challenging in regions with a country border. In these regions a close cooperation between the project partners was necessary. Data from both sides of the border were exchanged (TUNB REP. ID 29, Geomol Rep. ID 24). In case of the TransGeoTherm project Rep. ID 2, a buffer zone was defined along the country boundary (**Figure 2**). This zone was modelled first by both partners together. The resulting model was not changed after finalization and then extended to the rest of the modelling area.

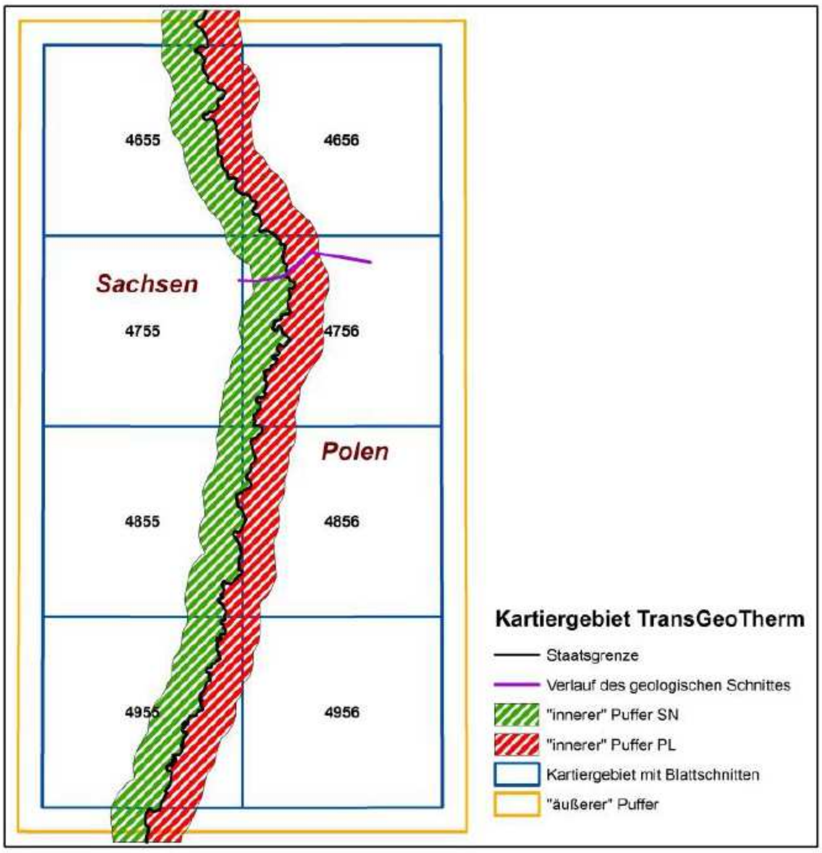


Figure 2: Inner buffer zone in the TransGeoTherm project.

3.3. Data processing and modelled objects

The 3D models comprise various **geological objects** like lithological units, i.e. stratigraphic or metamorphic units, aquifers and aquitards, fault networks, intrusive bodies or the groundwater table. The modelled units were represented in two different ways (**Figure 3**): either as volumetric representation (NL3D and Geotop Rep. ID 23, Influins Rep. ID 4) or as boundary surfaces (UK3D REP. ID 3, ISONG REP. ID 26). Volumetric representations can be directly parameterized with physical properties like porosity or specific thermal conductivity and can directly be used in one specific geothermal modelling programme. However, since the full volume of the modelling domain is discretized, this representation requires a lot of storage capacity. Surface representations need much less storage capacity. However, they have to be converted into a volume discretization prior to applying the physical parameters and running the geothermal calculations. On the other hand, the boundary representation can be used in various software systems, since it can be described flexibly by various cell types.

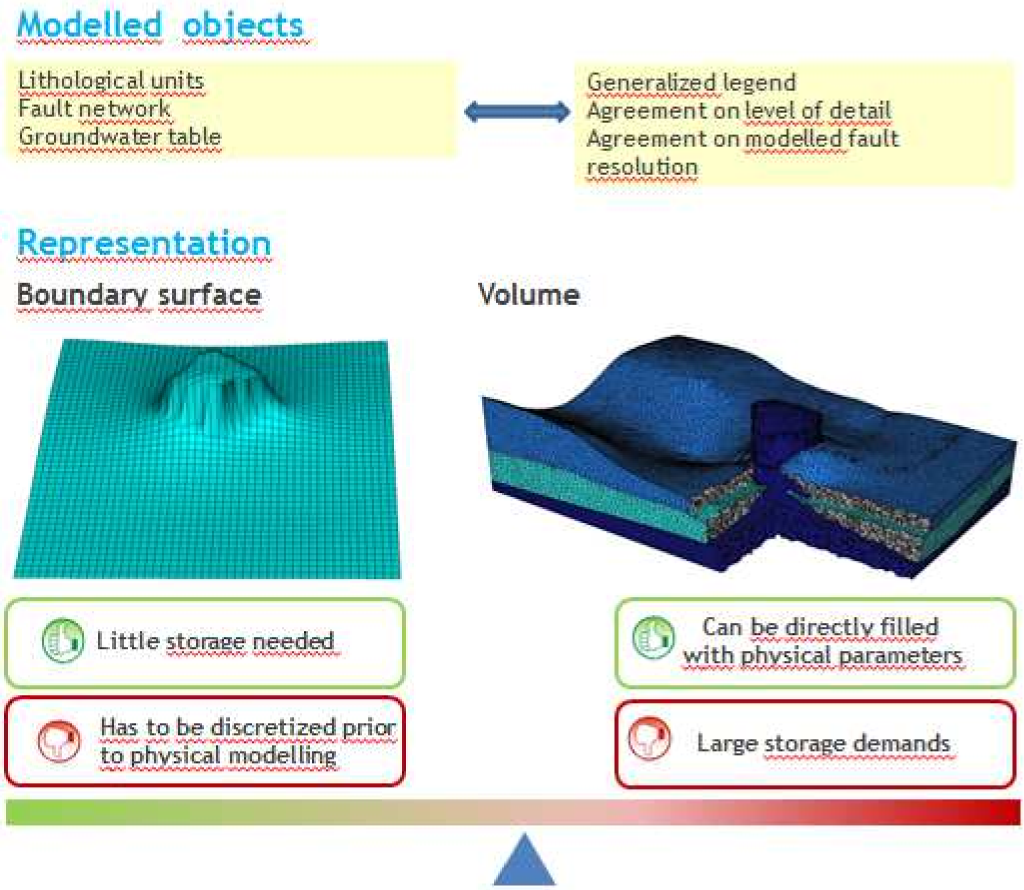


Figure 3: Modelled objects and possible representations of them by boundary surfaces or volumes.

The **boundary surfaces** of lithological units can be described in various ways (**Figure 4**):

- closed boundary polygons,
- top horizons,
- base horizons.

If the boundary of a unit is described by a closed polygon, it is unequivocal, which geological body the boundary surface belongs to. However, all boundaries inside of the modelling domain have to be stored twice, since they separate two bodies. Faults and horizons, tops and sides of a body cannot be distinguished anymore, which might complicate the use of this sort of model for calculations of the geothermal potential. Modelling the horizon tops allows building up a 3D model from top down, which means that the units with the most detailed information can be modelled first. If the horizon tops are used in a model, it is always known, which units occur in the whole model, although it is not clear, which unit is located above one specific boundary surface. Many 3D modelling and geothermal calculation software tools use the top horizons (i.e. Petrel, Skua structure and stratigraphy workflow, ArcGIS geothermal extension). Stratigraphic units are usually defined by their base, such that working with the top horizons requires special care during the data preparation. If horizon bases are modelled, the stratigraphic descriptions of geological maps and well documentations can be used directly. However, the model has to be built up from bottom to top. Since usually few data and details about the unit geometry is available in greater depths, but many data is available in the shallow parts of the model, this modelling technique may result in inconsistencies like horizon crossings. Additionally, that part of the model which is located below the last base horizon is not specified.

The project HyK 50 Rep. ID 28 works with boundary polygons, the projects NL3D and GeoTop Rep. ID 23 as well as Influins Rep. ID 4 work with horizon tops, Geomol Rep. ID 24, UK3D REP. ID 3 and GeotIS Rep. ID 25 with horizon bases. The project TransGeoTherm Rep. ID 2 provides both horizon tops and bases. In addition to the boundary models, the projects NL3D and GeoTop Rep. ID 23 comprise a volume model.

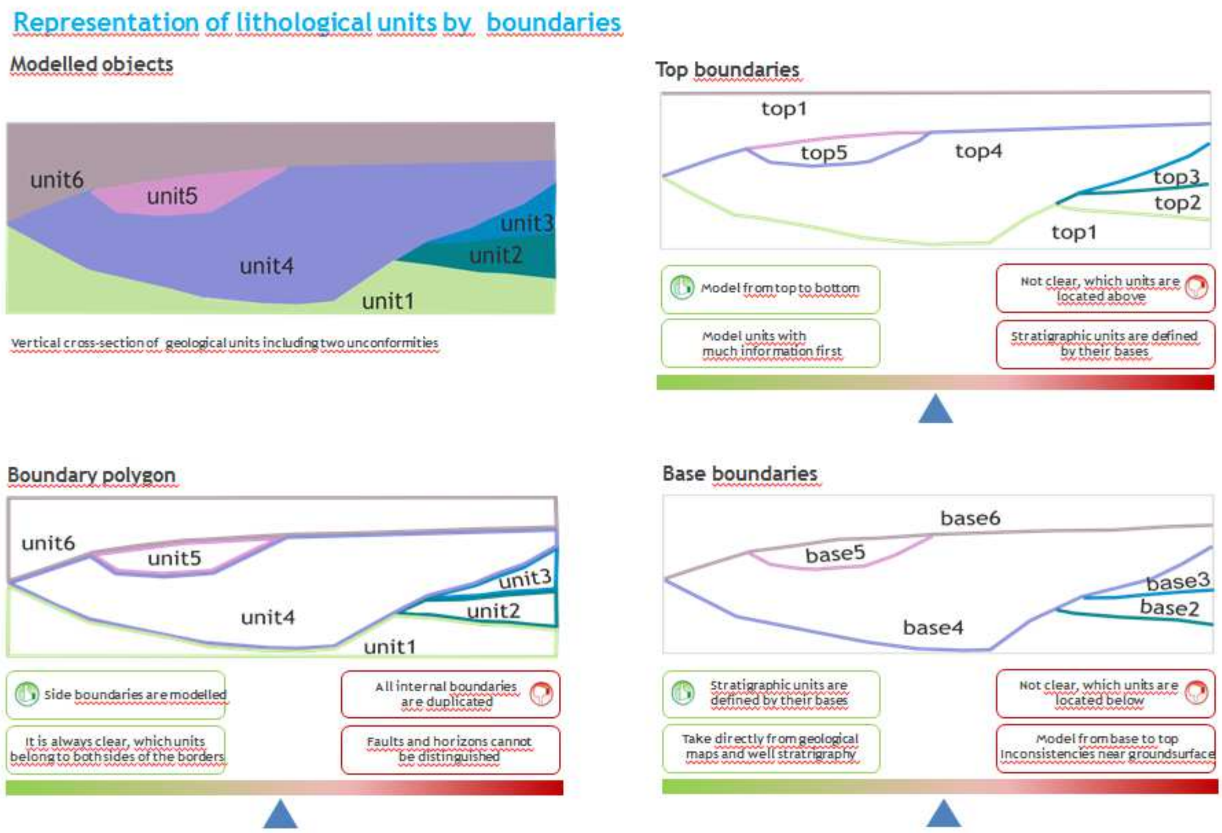


Figure 4: various representations of boundaries of lithological units, advantages and disadvantages.

Both, the volume and the surface models can be described by different data structures (Figure 5). Raster data structures describe an object by a regular grid of cells, i.e. as 2D grid or as voxet. The origin, the numbers of cells and the step width in each spatial direction have to be stored. Models in this data structure are characterized by a regular equidistant set of model points. Therefore, they can be easily checked for inconsistencies. The borders of the modelled objects have a stair-case shape, sharp angles cannot be represented. The data structure of the SGrid allows the deformation of the grid parallel to stratigraphic boundaries and major faults. Vector data structures describe an object by an irregular set of points, i.e. by a point cloud, triangulated surface or a tetrahedral mesh. The spatial coordinates are saved for each point. If a surface or a tetrahedral mesh has to be specified by a vector model, a topological model has to be saved in addition to the data points, specifying which points belong to one cell. Objects modelled in this data structure are very flexible concerning their shape and their resolution. However, inconsistencies can be found more difficult than in a regular grid. Due to the flexible shape, one cell may be strongly distorted, which may cause artefacts or problems during numerical simulations. NL3D and GeoTop Rep. ID 23 worked with 2D grids and voxets, Influis Rep. ID 4 with 2D grids and SGrids. HyK 50 Rep. ID 28 generates 2D grids. TransGeoTherm Rep. ID 2, GeotIS Rep. ID 25, UK3D REP. ID 3 and ISONG REP. ID 26 used triangulated surfaces. Geomol Rep. ID 24 and TUNB REP. ID 29 worked with various data structures in order to join the different modelling methods of the project partners.

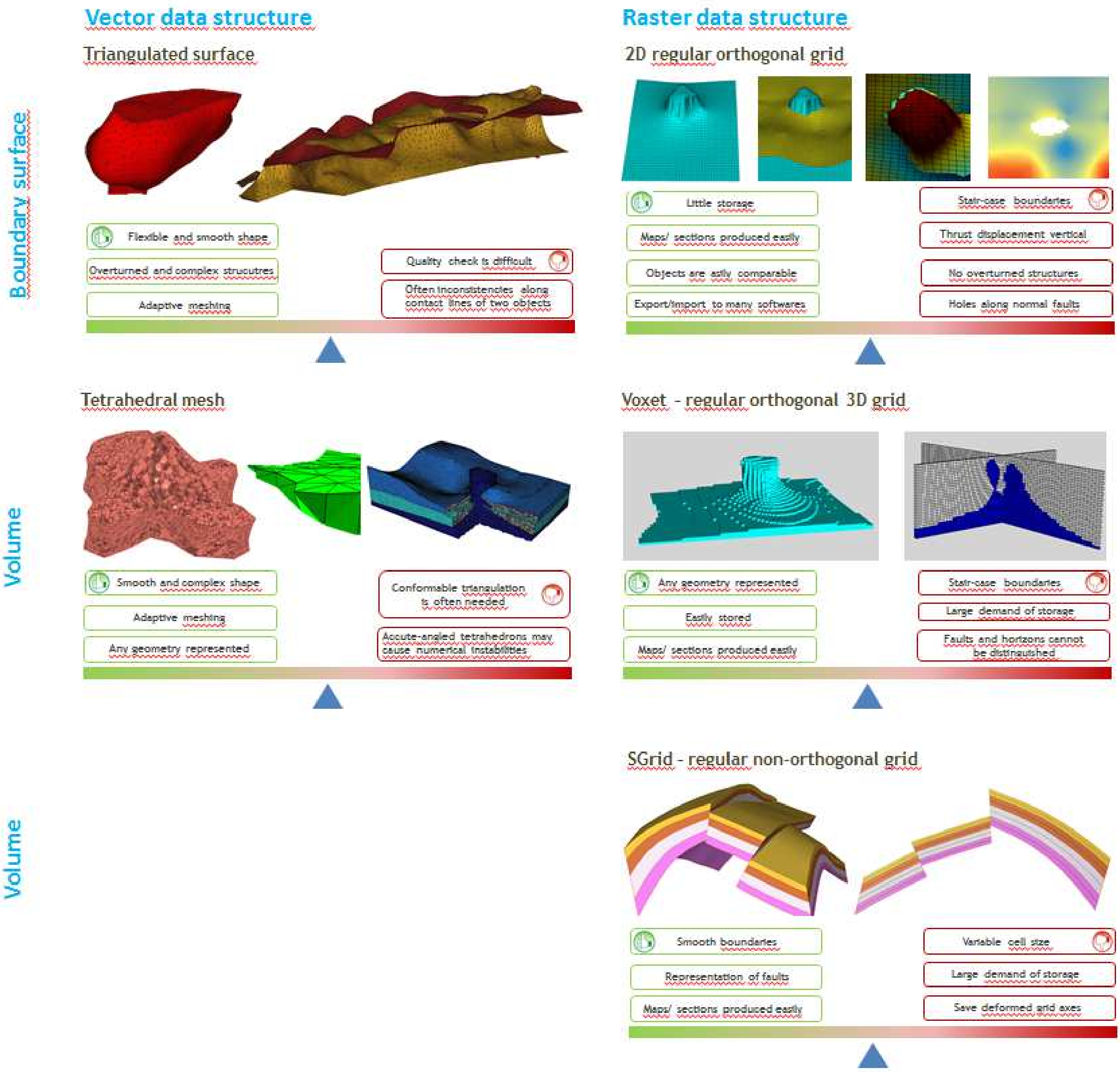


Figure 5: data structures available for 3D structural models.

3.4. Modelling workflows

All screened 3D modelling workflows follow the same logical procedure: First, the fault network is modelled, and then the lithology is modelled for each fault block.

Modelling workflows generating the lithology from top to bottom are especially convenient, since near the ground surface most data are available and details are known, while the density of data and thus the knowledge about details is decreasing downward. However, the models of the upper units have to be consistent with the ground surface and the deep units have to be consistent with the upper units. Therefore, it is beneficial to model the upper units first in order to avoid crossings and inconsistencies (ISONG REP. ID 26, NL3D Rep. ID 23, HyK50 Rep. ID 28).

If stratigraphic units are modelled, unconformities are very important, since they cut sequences of conformable units. Therefore, unconformities should be modelled first and the space between two unconformities should be filled with conformable sequences, such that they terminate properly at the unconformity (Influins Rep. ID 4, TUNB REP. ID 29).

Two kinds of modelling approaches are used for geological structural modelling: explicit and implicit methods.

Explicit methods describe geological objects by explicit equations of the form:

$y = f(x);$

The dependent variable can be written uniquely and explicitly in terms of the independent variable. Objects with multiple dependent variables cannot be described, like folds or diapirs.

Working with this method, a boundary surface is constructed explicitly, i.e. as triangulated mesh, and then fitted to the geological data. Geological bodies can be constructed from a framework of boundary surfaces. If the boundary surfaces were constructed independently, the body modelling may become inconsistent. The advantage of this method is that it is easy to understand and apply by the user.

Explicit modelling approaches were applied in the following projects:

- ***UK3D REP. ID 3*** works mostly with the software GSI3D. In this software, fence diagrams are constructed describing the intersection lines of geological horizons with a cross-section. These contact lines are connected to triangulate horizon surfaces by bilinear interpolation. This modelling approach is easy to handle, but not suitable for modelling complex structures.
- The projects ***TransGeoTherm Rep. ID 2and GeotIS Rep. ID 25*** work with the software Gocad. In this software, a triangulated point set medium plane is generated as a regression plane of the data and then fitted by the Discrete Smooth Interpolation (DSI) algorithm. This procedure minimizes the distance of the data to the surface and the global roughness of the surface. In regions with few data points, horizon crossings may occur, which can be corrected by using thickness constraints setting a minimum distance between two horizons.
- The project ***ISONG REP. ID 26*** also works with Gocad, but with a different modelling workflow. The modelling is performed downward, and a thickness property is propagated from the triangulated boundary surfaces by a tetrahedral mesh representing the interpolated unit thickness. This modelling approach avoids horizon crossings from the very beginning; however, artefacts may be propagated from units with many data and details to units with view data.
- The project **HyK 50 Rep. ID 28** as basis of Geothermieatlas Sachsen uses an explicit modelling approach, which can be realized with various software packages like Surpack, Gocad, ArcGIS. The modelled objects are a specific combination of a raster and a vector data model. They consist of regular quadratic cells, each of which is characterized by the XYZ coordinates of its corner points. In order to guarantee the conformability of all parts of the model, a master grid is generated, which

specifies all grid points in a region. These master points are used as grid corner points for all units of the 3D model.

- The projects ***NL3D and GeoTop Rep. ID 23*** use the software Petrel, which provides the most advanced explicit modelling approach. This software works with the Pillar Gridding Technique, which produces 2D grids. The workflow starts with defining key pillars along the faults, which are connected to fault planes. The center points of the key pillars are connected by a mid-plane between all faults. A set of pillars is constructed perpendicular to this mid-plane filling the whole modelling domain and a bottom, mid and top grid skeleton grid are produced. From this skeleton, all horizon grids are produced at the same time from the data points and interpretation lines taking into account the relation between the horizons like onlaps or truncations. The advantage of this workflow is that data from all horizons are used together for modelling and a consistent set of surfaces is generated. The disadvantage is that non-cylindrical and overturned structures cannot be modelled.

Implicit modelling methods work with implicit formulas of the form

$0 = f(x,y);$

They calculate a scalar field from the geological data for the whole modelling domain. The data of each geological object represent one constant value. The boundary surfaces can be extracted from the scalar field by calculating an iso-surface with the specific constant value representing the object boundary. Since this surface is described by an implicit formula, objects with complex shapes and multiple z-values can be described properly. Implicit modelling approaches generate the body first and extract the surface afterwards. This has the advantage that no inconsistencies occur. The disadvantage of these methods is, that they are more complex and difficult to understand. The user needs more training.

Implicit modelling approaches were applied in the following projects:

- ***Influins Rep. ID 4*** works with the Skua structure and stratigraphy workflow. Here, the scalar field is calculated on a tetrahedral mesh. First, the faults are interpolated, and triangulated surfaces representing the fault network are extracted. Next, the tetrahedral mesh is re-meshed and the fault surfaces become facets of the tetrahedrons. Then, the stratigraphic units are interpolated in common as scalar field on the tetrahedral mesh, taking into account the relation between the units like erosion and baselap. In the next step the horizon surfaces are extracted by an implicit function and represented as a 2D grid. The advantage of this method is, that erosional unconformities can be modelled very efficiently; units with view data “get help” from units with many data and consistent lithological bodies are calculated. The disadvantage is that only stratigraphic sequences can be modelled, veins or complex intrusions cannot be modelled with this workflow.
- The project ***Markovec and Karavanke tunnel Rep. ID 27*** works with the software Leapfrog. Here, a continuous function is calculated to describe the geological objects in the whole modelling domain. Locations with a constant value can be described by implicit iso-surfaces. Leapfrog allows modelling of complex intrusions and vein systems in addition to sedimentary units. Each geological body is modelled independently, but all bodies are intersected by Boolean operations according to their structural relationship and relative ages. This modelling workflow allows a consistent modelling of metamorphic and magmatic rocks.

4. Summary and Conclusions

4.1. Input from research of projects

All modelling workflows results in consistent 3D models of the lithological units important for the purpose of the project. Every workflow has advantages and disadvantages and was selected due to the special characteristics of the input data, the project and the modelling software. Depending on the selected modelling software, the geometrical objects are produced in different kinds of data models. The most common kind of representation is the boundary surface. This is either described by vector or raster data structures. A conversion of the data structure was necessary in some projects, if the data structure produced with the 3D modelling software was not usable for the subsequent steps of the parameter modelling or the model visualization (GeotIS Rep. ID 25, Geothermieatlas Sachsen Rep. ID 28, TransGeoTherm Rep. ID 2).

The projects provide an insight on which **parameters have to be specified prior to 3D modelling:**

- One spatial and elevation reference system is needed.
- The horizontal and vertical extension of the modelling domain has to be specified.
- The project partners have to specify, which geological objects have to be modelled.
- The resolution of the model has to be specified. This determines the level of detail in which the geological objects can be described.
- Taking into account the previously listed specifications, a harmonized legend of all modelled geological units has to be produced.
- In addition, a harmonized fault network with a defined level of detail has to be specified.
- Harmonized rules on the description of the groundwater table have to be defined.
- The desired representation of the modelled geological bodies has to be defined (top, base or envelop).
- In cross-border pilot areas, a buffer zone along the state border has to be defined, where both partners generate a common 3D model which must not be changed later. From this buffer zone, 3D modelling is extended to the full pilot area.

All these specifications, definitions and rules have to be applied during data preparation, such that a harmonized input data set is produced.

During the 3D geometry modelling, various **geological objects** can be modelled:

- Faults,
- Shear zones,
- Detachments,
- Stratigraphic units,
- Facies bodies,
- Metamorphic units,
- Volcanic bodies,
- Intrusive bodies,
- Vein systems or
- The groundwater table.

These objects can be represented by

- Volumes or
- Surfaces.

Unit boundaries may be represented by

- Top horizons,
- Base horizons or
- Envelops of closed boundary polygons.

Models representing the top surfaces seem to be especially suitable, since they can be combined with an efficient modelling workflow working from top downward and thus from regions with many data to regions with few data. This modelling approach can avoid inconsistencies in the 3D model.

The data structure and data model of the modelled representations has to be specified.

- Vector structure:
- Triangulated surface,
- Tetrahedral mesh.
- Raster structure:
- 2D grid,
- Voxet,
- SGrid.

Raster and vector data structures are available in different modelling software. Additionally, the data structure required for the subsequent use of the model has to be taken into consideration. In best case, 3D modelling produces a data structure which can be directly used for the potential modelling and the model visualization.

A harmonization of all parameters is necessary, the more parameters can be harmonized for all project partners and pilot areas, the more conformable and the better comparable the modelling results are.

4.2. Technique of 3D modelling of the project partners

The project partners work with various modelling software, data structures and geothermal simulation software. **Table 2** provides an overview. One data structure which is used by almost all partners and can be produced by all partners is the 2D grid data model. Additionally, working with top horizons seems to be possible.

Table 2: Modelling software, data structure and object representation used by GeoPLASMA-CE partners.

	Software	Data structure	Data model	Representation of geological objects
3D modelling	Skua	Vector	TSURF	Unit top
	Move	Vector	TSURF	Unit top or base
	Petrel	Raster	2D grid	Unit top
	Jewel	Raster	2D grid	Unit top or base
Geothermal simulation	ArcGIS	Raster	2D grid	Unit top
	FE Flow	Vector+ Raster	2D grid + TSURF	Unit top+ Unit base

4.3. Suggestions for a common workflow

As a result of this research, we propose a 3D modelling workflow the GeoPLASMA-CE project team as listed in **Table 3**. All specifications should be useable for all project partners and should be discussed at the next GeoPLASMA-CE workshop.

Table 3: Checklist for specifications of the 3D modelling workflow for the GeoPLASMA-CE team.

Definitions	For all partners	Specific for pilot areas
Spatial reference	ETRS1989 UTM north	**UTM zone**
Elevation reference	-	Each pilot area
Level of detail	Two scales 1: 10 000 1: 50 000	Descision for one in each pilot area (independent)
Modelling domain	200 m depth	Buffer zones along borders
Harmonized fault network	Each pilot area	Buffer zones along borders
Harmonized legend	Each pilot area	Buffer zones along borders
Modelled objects	Faults Lithological units Groundwater table	-
Representation of objects	Boundary surface Unit top	-
Data model	2D grid Master grid or reference points	-

5. References

A research of literature gives an overview of already existing methods of geological based 3D-modelling, geothermal potential mapping in general and land-use-conflict mapping related to geothermal energy. The results of this research are compiled into a developed “knowledge repository”.

63 national and international projects related to the main topics of GeoPLASMA-CE are stored as publications for further research in the database “knowledge repository”. These projects and publications were assessed and are partly linked to workpackages of GeoPLASMA-CE. The main focus of the research was the methodical approach to geological 3D-modelling, geothermal mapping for open and closed loop systems and land-use conflict mapping concerning geothermal potential mapping in regional and urban areas. Additionally, there were registered any other interlinks to technical workpackages 1, 3 and 4 and some possible experiences for workpackage communication.

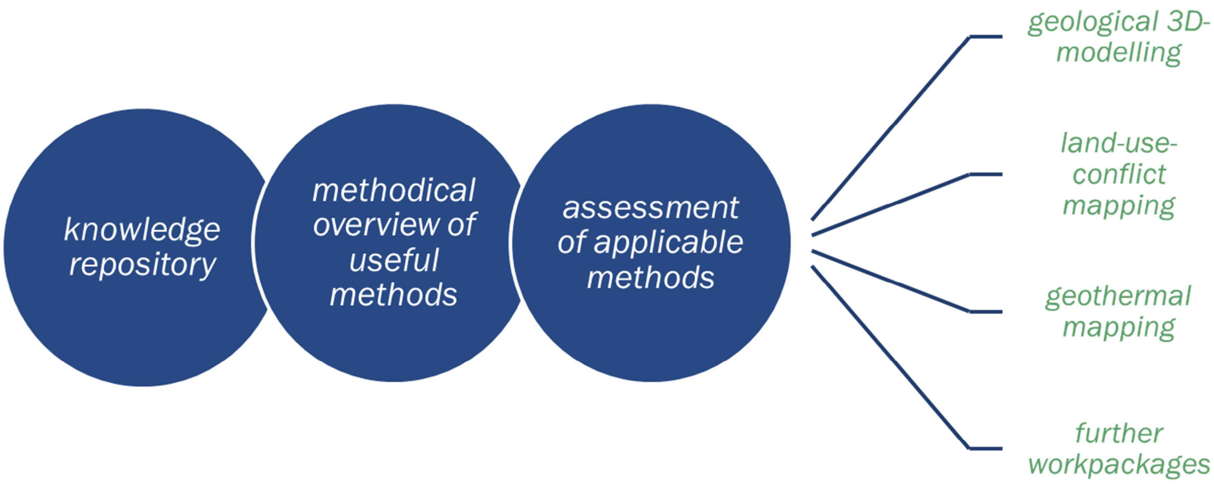


Figure 6: methodical research

The list of the knowledge repository with the methodical assessment and linkages to other workpackages is summarized at table 5.

All assessment sheets are added in Annex 1 for further information.

Table 4: knowledge repository methodical research

ID	literature type	Year/ last access date	Author	Title	Publisher, journal issue, vol., pp.	usefull for WP	linked to WP	Keyword1	Keyword2	Keyword3	web link (if available)
1	published	2014	Arola, T., Eskola, L., Hellen, J., Korkka-Niemi, K.	Mapping the low enthalpy geothermal potential of shallow Quaternary aquifers in Finland	Springer, Geothermal Energy, vol. 2, 9	TWP2		potential mapping	open-loop system		
2	published	2014	LfULG, PGI	Handbuch zur Erstellung von geothermischen Karten auf der Basis eines grenzübergreifenden 3D-Untergrundmodells; Podręcznik opracowywania map geotermicznych na bazie transgranicznego trójwymiarowego (3D) modelu podłoża	Sächsisches Landesamt für Umwelt, Landwirtschaft und Geologie;Państwowy Instytut Geologiczny - Państwowy Instytut Badawczy, Oddział Dolnośląski (PIG-PIB OD)	TWP2	TWP4	3D-modelling	potential mapping	use in regional areas	http://www.transgeotherm.eu/publikationen.html
3	published	2015	LfULG	TransGeoTherm Rep. ID 2- Erdwärmepotenzial in der Neiße-Region	Sächsisches Landesamt für Umwelt, Landwirtschaft und Geologie, Schriftenreihe	TWP2	TWP4	3D-modelling	(hydro)geology of pilot area	use in regional areas	http://www.transgeotherm.eu/publikationen.html
4	unpublished	2015	Peters, A.	Oberflächennahes geothermisches Potential in Thüringen	Thüringer Landesanstalt für Umwelt und Geologie	TWP2	TWP3	potential mapping	use in regional areas	closed-loop system	
5	published	2015	Epting, J., García-Gil, A., Huggenberger, P., Müller, M., Vázquez-Suñe, E.	Development of concepts for the management of thermal resources in urban areas - Transferable concepts on the basis of the experience from the Basel and Zaragoza case studies	Short-term Scientific Mission (STSM), Institute of Environmental Assessment and Water Research (IDÆA), UPC, Barcelona, Spain.	TWP2		use in urban areas	heat storage	monitoring	
6	published	2013	Zosseder, G., Chavez-Kus, L., Somogyi, G., Kotyla, P., Kerl, M., Wagner, B., Kainzmaier, B.	GEPO - Geothermisches Potenzial der Münchener Schotterebene Abschätzung des geothermischen Potenzials im oberflächennahen Untergrund des quartären Grundwasserleiters des Großraum Münchens. GEPO - Geothermal potential of the Munich Gravel Plain Assessment of the geothermal potential in the shallow subsurface of the Quaternary aquifer in the Greater Munich.	19. Tagung für Ingenieurgeologie mit Forum für junge Ingenieurgeologen München 2013	TWP2		field measurements	groundwater	use in urban areas	
7	published	2014	Götzl, G., Fuchsluger, M., Rodler, A., Lipiarski, P., Pfleiderer, S.	Projekt WC-31 Erdwärmepotenzialerhebung Stadtgebiet Wien, Modul 1	Abteilung MA20 - Energieplanung des Magistrats der Stadt Wien	TWP2	TWP3	potential mapping	open-loop system	closed-loop system	https://www.wien.gv.at/stadtentwicklung/energieplanung/stadtplan/erdwaerme/erlaeuterungen.html
8	published	2014	LfULG, PGI	Informationsbroschüre zur Nutzung oberflächennaher Geothermie, Broszura informacyjna na temat stosowania płytkiej geotermii	Sächsisches Landesamt für Umwelt, Landwirtschaft und Geologie; Państwowy Instytut Geologiczny - Państwowy Instytut Badawczy, Oddział Dolnośląski (PIG-PIB OD)	TWP4		closed-loop system	quality standards	policy strategies	http://www.transgeotherm.eu/publikationen.html
9	published	2016	Malík, P., Švasta, J., Gregor, M., Bačová, N., Bahnová, N., Pažická, A.	Slovak Basic Hydrogeological Maps at a Scale of 1:50,000 - Compilation Methodology, Standardised GIS Processing and Contemporary Country Coverage	State Geological Institute of Dionýz Štúr Bratislava 2016, Slovak Republic, Slovak Geological Magazine, vol.16, no.1, ISSN 1335-096X	TWP2	TWP1	groundwater	(hydro)geology of pilot area	use in regional areas	

ID	literature type	Year/ last access date	Author	Title	Publisher, journal issue, vol., pp.	usefull for WP	linked to WP	Keyword1	Keyword2	Keyword3	web link (if available)
10	published	2016	Bodiš, D., Rapant, S., Kordík, J., Slaninka, I.	Groundwater Quality Presentation in Basic Hydrogeochemical Maps at a Scale of 1:50,000 by Digital Data Treatment Applied in the Slovak Republic	State Geological Institute of Dionýz Štúr Bratislava 2016, Slovak Republic, Slovak Geological Magazine, vol.16, no.1, ISSN 1335-096X	TWP2		groundwater	quality standards	use in regional areas	
11	published	2016	Fričovský, B., Černák, R., Marcin, D., Benková, K.	A First Contribution on Thermodynamic Analysis and Classification of Geothermal Resources of The Western Carpathians (an engineering approach)	State Geological Institute of Dionýz Štúr Bratislava 2016, Slovak Republic, Slovak Geological Magazine, vol.16, no.1, ISSN 1335-096X	TWP2		heat storage	groundwater	use in regional areas	
12	published	2014	Ditlefsen, C., Sorensen, I., Slott, M., Hansen, M.	Estimation thermal conductivity from lithological descriptions - a new web-based tool for planning of ground-source heating and cooling	Geologcial Survey of Denmark and Greenland Bulletin, vol.31, 55-58	TWP2	TWP1	closed-loop system	thermal conductivity		http://geuskort.geus.dk/termiskejordarter/
13	published	2004	Goodman, R., Jones, G. Ll., Kelly, J., Slowey, E., O'Neill, N.	Geothermal Resource Map of Ireland	Sustainable Energy Authority of Ireland	TWP2	TWP1	closed-loop system	open-loop system	potential mapping	http://maps.seai.ie/geothermal/
14	published	2010	Goodman, R., Jones, G. Ll., Kelly, J.	Methodology in Assessment and Presentation of Low Enthalpy Geothermal Resouces in Ireland	World Geothermal Congress 2010	TWP2	TWP1	field measurements	3D-modelling		
15	published	2016		ThermoMap		TWP2	TWP1	closed-loop system	potential mapping	(hydro)geology of pilot area	http://www.thermomap-project.eu/
16	published	2012	Abesser, C.	Technical Guide - A screening tool for open-loop ground source heat pump schemes (England and Wales)	BGS and EA	TWP2		open-loop system	potential mapping	groundwater	http://mapapps2.bgs.ac.uk/gshpnational/home.html
17	published	2012	Rajver, D., Pestotnik, S., Prestor, J., Lapanje, A., Rman, N., Janža, M.	Possibility of utilisation geothermal heat pumps in Slovenia (Geothermal resources in Slovenia)	Geological Survey of Slovenia, Bulletin Mineral resources in Slovenia 2012, (165-175)	TWP2		potential mapping	use in regional areas		http://www.geo-zs.si/PDF/PeriodicnePublikacije/Bilten_2012.pdf
18	published	2016	Borović, S., Urumović, K., Terzić, J.	Determination of subsurface thermal properties for heat pump utilization in croatia	Third Congress of Geologists of Republic of Macedonia.	TWP2	TWP3	field measurements	closed-loop system		http://geothermalmapping.fsb.hr
19	published	2015	Holeček J., Burda J., Bílý P., Novák P., Semíková H	Metodika stanovení podmínek ochrany při využívání tepelné energie zemské kůry	GEOTERMAL,TAČR project No.: TB030MZP024	TWP2	TWP4	land-use conflicts			
20	unpublished	2013		Tepelná čerpadla pro využití energetického potenciálu podzemních vod a horninového prostředí z vrtů (Heat pumps and exploitation of the energy potential of underground water and rock environment from wells)		TWP2	TWP4				
21	unpublished	2009	P. Hanžl, et al.	Basic guidelines for the preparation of a geological map of the Czech Republic 1: 25000		TWP2		3D-modelling			
22	published	2016	Götzl, G., Pfleiderer, S., Fuchsluger, M., Bottig, M., Lipiarski, P.	Projekt SC-27, Pilotstudie „Informationsinitiative Oberflächennahe Geothermie für das Land Salzburg (IIOG-S)	Geologische Bundesanstalt	TWP2		closed-loop system	open-loop system	potential mapping	

ID	literature type	Year/ last access date	Author	Title	Publisher, journal issue, vol., pp.	usefull for WP	linked to WP	Keyword1	Keyword2	Keyword3	web link (if available)
23	published	2013	van der Meulen	3D geologpy in a 2D country: perspectives for geological surveying in the Netherlands	Netherlands Journal of Geosiences, 92-4, page 217-241, 2013	TWP2		3D-modelling			
24	published	2015	LfU	Geomol Rep. ID 24 - Assessing subsurface potentials of the Alpine Foreland Basins for sustainable planning and use of natural resources. Project Report		TWP2		potential mapping			http://www.Geomol Rep. ID 24.eu
25	published		Agemar (2014, 2016) Gocad-Anwendertreffen	GeoTIS		TWP2	TWP1	3D-modelling	potential mapping		https://www.geotis.de/geotisapp/geotis.php
26	published		LBRG	ISONG REP. ID 26: Informationssystem für oberflächennahe Geothermie Baden Württemberg		TWP2	TWP1	3D-modelling	potential mapping	land-use-conflict mapping	http://ISONG Rep. ID 26.lgrb-bw.de/
27	published	2007	Joris Ondreka, Maike Inga Rüsgen, Ingrid Stober, Kurt Czurda	ISONG REP. ID 26: GIS-supported mapping of shallow geothermal potential of representative areas in south-western Germany—Possibilities and limitations	Renewable Energy 32 (2007) 2186-2200	TWP2	TWP1	potential mapping	closed-loop system	3D-modelling	
28	published	2014	LfULG	Geothermieatlas Sachsen: Allgemeine Erläuterungen zum Kartenwerk der geothermischen Entzugsleistungen im Maßstab 1:50 000 GTK 50	Sächsisches Landesamt für Umwelt, Landwirtschaft und GeologiePillnitzer Platz 3, 01326 Dresden	TWP2	TWP3	potential mapping	closed-loop system	use in regional areas	
29	unpublished			TUNB REP. ID 29		TWP2					
30	published	2015	D. Bertermann, H. Klug, L. Morper-Busch	A pan-European planning basis for estimating the very shallow geothermal energy potentials	Renewable Energy 75 (2015) 335-347	TWP2		potential mapping			
31	published	2016	Casasso, Sethi	G.POT A quantitative method for the assessment and mapping of the shallow geothermal potential		TWP2		potential mapping			
32	published	2015	Galgaro et al.	Empirical modeling of maps of geo-exchange potential for shallow geothermal energy at regional scale		TWP2		potential mapping			
33	published		Phillipe Dumas et al.	ReGeoCities Final Report		TWP4		use in urban areas	policy strategies	quality standards	
34	published	2011	Gemelli, Mancini, Longhi	GIS-based energy-economic model of low temperature geothermal resources A case study in the Italian Marche region	Renewable Energy 36 (2011) 2474-2483	TWP2		policy strategies			
35	published	2002	Hamada et al.	Study on underground thermal characteristics by using digital national land information, and its application for energy utilization	Applied Energy 72 (2002) 659-675	TWP2		potential mapping			
36	published	2016	Hein et al.	Potential of shallow geothermal energy extractable by Borehole Heat Exchanger coupled Ground Source Heat Pump systems	Energy Convension and Management 127 (2016) 80-89	TWP2		potential mapping	closed-loop system		
37	published	2011	Nam, Ooka	Development of potential map for ground and groundwater heat pump systems and the application to Tokyo		TWP2		potential mapping	use in urban areas		

ID	literature type	Year/ last access date	Author	Title	Publisher, journal issue, vol., pp.	usefull for WP	linked to WP	Keyword1	Keyword2	Keyword3	web link (if available)
38	published			Adriatic IPA project LEGEND: Low enthalpy geothermal energy demonstration		TWP4		quality standards	policy strategies		http://www.adriaticipacbc.org/login.asp
39	published			Cheap-GSHPs: Cheap and efficient application of reliable ground source heat exchangers and pumps		TWP2	TWP4	quality standards	policy strategies		http://cheap-gshp.eu/
40	website			COST-Action GABI: Geothermal energy Applications in Buildings and Infrastructure		TWP4		quality standards	potential mapping		https://www.foundationgeotherm.org/
41	website			EGIP: European Geothermal Information Platform		WPC		policy strategies			http://egip.igg.cnr.it/
42	published			FROnT: Fair Renewable Heating and Cooling Options and Trade		TWP4	WPC	policy strategies	quality standards		http://www.front-rhc.eu/
43	website			GEOTeCH: Geothermal Technology for €conomic Cooling and Heating		WPC	TWP3	field measurements	quality standards		http://www.geotech-project.eu/
44	website			Geothermal ERA-NET		TWP1	WPC	use in regional areas	policy strategies		http://www.geothermaleranet.is/
45	published			GEOTRAINET: Geo-Education for a sustainable geothermal heating and cooling market		TWP4	WPC	quality standards			http://geotrainet.eu/
46	website			Green Epile: Development and implementation of a new generation of energy piles		WPC					http://cordis.europa.eu/project/rcn/204589_en.html
47	published			IMAGE: Integrated Methods for Advanced Geothermal Exploration		TWP2	TWP3	field measurements	use in regional areas		http://www.image-fp7.eu/Pages/default.aspx
48	website			ITER: Improving Thermal Efficiency of horizontal ground heat exchangers		WPC		monitoring	field measurements		http://iter-geo.eu/
49	website			ITHERLAB: In-situ thermal rock properties lab		TWP3		field measurements			http://cordis.europa.eu/project/rcn/201131_en.html
50	website			TERRE:Training Engineers and Researchers to Rethink geotechnical Engineering for a low carbon future		WPC		quality standards			http://www.terre-etn.com/
51	website			TESSe2b:Thermal Energy Storage Systems for Energy Efficient Buildings. An integrated solution for residential building energy storage by solar and geothermal resources		TWP4		heat storage	quality standards		http://www.tesse2b.eu/tesse2b/newsTesse2bProject
52	website			TRANSENERGY, legal aspect of transboundary aquifer management		TWP2	TWP4	3D-modelling			http://transenergy-eu.geologie.ac.at/

ID	literature type	Year/ last access date	Author	Title	Publisher, journal issue, vol., pp.	usefull for WP	linked to WP	Keyword1	Keyword2	Keyword3	web link (if available)
53	website	2016		GRETA		TWP2	TWP4	quality standards	use in regional areas	policy strategies	http://www.alpine-space.eu/projects/greta/en/home http://www.alpine-space.eu/projects/greta/en/project-results/reports/deliverables
54	website		LfU	IOG Bayern	LfU	TWP2	TWP1	open-loop system	closed-loop system	land-use-conflict mapping	http://www.lfu.bayern.de/geologie/geothermie_iog/
55	website		LBEG	NIBIS, Niedersachsen	LBEG	TWP2	TWP1	potential mapping	land-use-conflict mapping	3D-modelling	http://nibis.lbeg.de/cardomap3/
56	website		lgb-rlp	Rheinland Pfalz	lgb-rlp	TWP2	TWP1	potential mapping	3D-modelling	land-use-conflict mapping	http://www.lgb-rlp.de/karten-und-produkte/online-karten/online-karten-geothermie.html
57	website		LLUR	Schleswig Holstein	LLUR	TWP2	TWP1	potential mapping			
58	published	Jun 16	Tina Zivec, Elea iC d.o.o., Slovenia	Markovec_USING 3D GEOLOGICAL MODELLING IN CIVIL INDUSTRY	3rd Europeanmeeting on 3D geologicalmodelling	TWP2		3D-modelling			
59	published	2014	S. J. Mathers, R. L. Terrington, C. N. Waters and A. G. Leslie	GB3D - a framework for the bedrock geology of Great Britain	Geoscience Data Journal 1: 30-42 (2014), RMetS	TWP2	TWP1	3D-modelling			
60	published	2011	Ad-hoc-AG Geologie, PK Geothermie	Fachbericht zu bisher bekannten Auswirkungen geothermischer Vorhaben in den Bundesländern		TWP2	TWP4	quality standards	land-use-conflict mapping		http://www.infogeo.de/home/geothermie/dokumente/index_html?sfb=8&sdok_typ=-1&skurzbeschreibung=
61	website		Geologischer Dienst NRW	Portal Geothermie Nordrhein-Westfahlen	Geologischer Dienst NRW	TWP2	TWP1	closed-loop system	land-use-conflict mapping		http://www.geothermie.nrw.de
62	published	2016	GSI	Ground Source Heating/Cooling System Suitability Maps - Open Loop Systems	GSI	TWP2	TWP2	open-loop system	potential mapping		
63	published	2016	GSI	Ground Source Heating/Cooling System Suitability Maps - Closed Loop Systems	GSI	TWP2	TWP2	closed-loop system	potential mapping		

Annex 1: methodical assessment sheets

Assessment sheet – TransGeoTherm, geothermal energy for the transborder development of the Neisse region

Please use this sheet for summarizing realized methods and approaches on both national as well as international level. Use one sheet per project / initiative and make sure to upload reports screened for this assessment on the joint knowledge repository, even in case the report is only available in national language!

Please insert information in the blue colored fields.

Project	TransGeoTherm

ID knowledge repository As indicated in register at Own Cloud	2	Reference Please use format: Author, Year, Title, Journal, Publisher	Handbuch zur Erstellung von geothermischen Karten auf der Basis eines grenzübergreifenden 3D-Untergrundmodells

Territorial coverage of study / initiative National – please indicate country; international – please indicate participating countries	Region Odra-Neisse in Germany and Poland

Thematic coverage of study / initiative Please tick topics	x	3D modelling methods with regard to the mapping of utilization potentials and risks
		Mapping of potential: open loop systems
	x	Mapping of potential: closed loop systems
		Mapping of land-use conflicts and risks, environmental impact assessment

Shallow geothermal utilization methods covered by project / initiative	Public version for location queries private builders With heat extraction capacity Professional version for planning consultant and drilling companies contains additionally the heat specific conductivity

Executive summary / synopsis of the report Maximum 1000 characters

3D modelling software
Gocad
Input data
Map data, drillings
Description of applied approach (methods and workflow)
Harmonized legend in a data base+ reference geological sections Buffer zone in the border region → is modelled first and not changed during the later work steps Modelling of top horizons and base horizons → TSurfs Rasterization by a "Master grid" which predefines the model points a the 2D grid used for the geothermal simulation
Output data
Triangulated surfaces 340 m depth Top horizon, base horizon and thickness, vertical "side" boundaries Conversion of the horizon tops into a 2D grid with 25 m step width → necessary for the geothermal calculation
Advantages
Disadvantages
Raster → tsurf → raster -> artefacts
Description of the suitability of the chosen approach for GeoPLASMA-CE

Parameter and potential model Input data
3D model →2D grid horizon tops 25 m resolution → valley sediments are not broader Groundwater table Specific thermal conductivity for wet and dry rocks on drilling cores
Software
ArcGIS
Approach/Workflow
Load the top horizons for each unit Load the ground water table Distinction of cases for wet and dry rocks → calculate the following for both: Parameterize the drillings with the specific conductivities Average conductivities of one drilling for the whole unit (upscaling) by a depth-weighted mean Assign the weighted mean to the raster cell of the top horizon of each unit Interpolate the specific thermal conductivities with the method of inverse distances Cut the raster according to the groundwater table: if the depth of the top horizon is smaller → assign dry conductivity, if the depth of the top horizon is greater → assign wet conductivity Calculate the specific thermal conductivities for 40, 70, 100, 130 m depth

Output data
25 m 2D Grid with specific heat conduction for 4 depth levels: 40, 70, 100, 130 m
Advantages
Disadvantages
Suitability for Geoplasma

Potential maps Input data
2D grid with specific thermal conductivity and depth of the top horizon
Software
ArcGIS ID Geothermal extension
Approach/Workflow
Calculate the specific heat extraction capacity by a empiric formula using the specific thermal conductivity: Entzugsleistung = -0,96 * λ_2 + 13,00 * λ + 29,60 (for 1800 h/a)
Output data
25 m 2D Grid with specific heat extraction capacity
Advantages
Disadvantages
Suitability for Geoplasma

Assessment sheet - UK3d

Please use this sheet for summarizing realized methods and approaches on both national as well as international level. Use one sheet per project / initiative and make sure to upload reports screened for this assessment on the joint knowledge repository, even in case the report is only available in national language!

Please insert information in the blue colored fields.

ID knowledge repository As indicated in register at Own Cloud	3	Reference Please use format: Author, Year, Title, Journal, Publisher	Mathers et al. 2012

Territorial coverage of study / initiative National – please indicate country; international – please indicate participating countries	England, Wales and Scotland

Thematic coverage of study / initiative Please tick topics	x	3D modelling methods with regard to the mapping of utilization potentials and risks
		Mapping of potential: open loop systems
		Mapping of potential: closed loop systems
		Mapping of land-use conflicts and risks, environmental impact assessment

Shallow geothermal utilization methods covered by project / initiative Please specify systems (e.g. borehole heat exchanger, groundwater well, horizontal collector)	

Executive summary / synopsis of the report Maximum 1000 characters
Consistent state 3d state model with major geological units and faults Detailed models are included stepwise

Description of input data used for mapping Please make a general sketch, no detailed data lists (e.g. hydrogeological maps scale 1:50.000)
Geological maps, drilling data, seismic data

Description of applied approach (methods and workflow) for mapping
Construction of lines representing major horizons in fence diagrams Connection of the lines to horizon surfaces by bilinear interpolation

Description of output parameters and data-formats of results e.g. printed maps including the scale, GIS based maps, interactive web-systems
Triangulated surfaces, processing required for volumetric parameterization

Description of the suitability of the chosen approach for GeoPLASMA-CE Please write a short review about the pros and cons of the chosen approach! Is that approach suitable for GeoPLASMA-CE?
Advanced project with interesting tools for querying and visualization in the www

NL3D and GeoTOP
3D geological state model of the Netherlands including a 3D model of hydrogeological parameters

Please use this sheet for summarizing realized methods and approaches on both national as well as international level. Use one sheet per project / initiative and make sure to upload reports screened for this assessment on the joint knowledge repository, even in case the report is only available in national language!

Please insert information in the blue colored fields.

ID knowledge repository As indicated in register at Own Cloud	23	Reference Please use format: Author, Year, Title, Journal, Publisher	Van der Meulen et al. (2013)

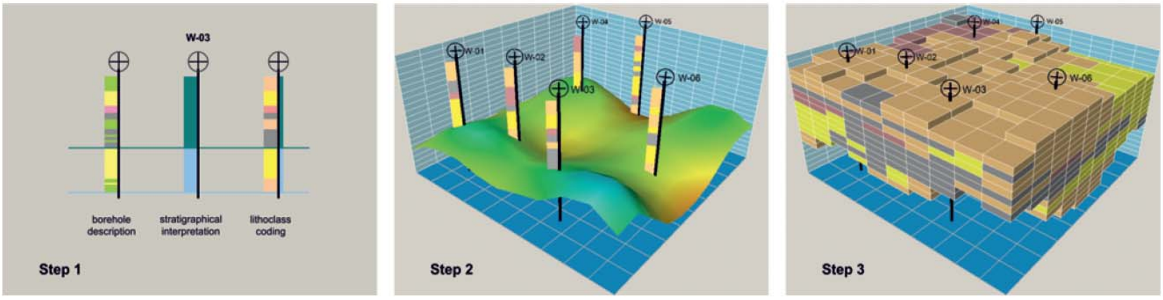
Territorial coverage of study / initiative National – please indicate country; international – please indicate participating countries	Netherlands

Thematic coverage of study / initiative Please tick topics	x	3D modelling methods with regard to the mapping of utilization potentials and risks
		Mapping of potential: open loop systems
		Mapping of potential: closed loop systems
		Mapping of land-use conflicts and risks, environmental impact assessment

Shallow geothermal utilization methods covered by project / initiative	None Assessment of recources Forcast of Land subsidence Hydraulic shortcut risk Groundwater studies

Executive summary / synopsis of the report Maximum 1000 characters
State 3D model up to 50 m depth, voxelized, available online

3D modelling software

Petrel, Isatis
Input data
Drillings, seimic, geological maps, hydraulic properties
Description of applied approach (methods and workflow)
Harmonized legend for different levels of detail Stacked-grid model of the bases of lithostratigraphic units Voxelisation of the subvolumes  *Fig. 6. Voxel modelling workflow. Borehole information is coded lithostratigraphically and as lithological classes (step 1). Lithostratigraphical unit boundaries are obtained just as in DGM, but using more data (step 2). Finally, lithostratigraphical units are voxelated (step 3). Modified from Stafleu et al. (2011).*
Output data
GeoTOP: Voxelise the subsurface in 100mx 100m x 0.5 m NL3D: 250m x 250 m x 1m To 50 m depth
Advantages
Can be directly used for calculation of chemical and physical parameters
Disadvantages
No overturned structures
Description of the suitability of the chosen approach for GeoPLASMA-CE
Well suitable, if a voxel-based simulation of the geothermal potential is required Good for finite difference method

Geomol – assessing subsurface potentials of the Alpine Foreland Basin for sustainable planning and use of natural resources

Please use this sheet for summarizing realized methods and approaches on both national as well as international level. Use one sheet per project / initiative and make sure to upload reports screened for this assessment on the joint knowledge repository, even in case the report is only available in national language!

Please insert information in the blue colored fields.

ID knowledge repository As indicated in register at Own Cloud	24	Reference Please use format: Author, Year, Title, Journal, Publisher	Diepolder et al. Geomol project report

Territorial coverage of study / initiative National – please indicate country; international – please indicate participating countries	France, Switzerland, Germany, Baden-Württemberg, Bavaria, Austria, Slovenia, Italia

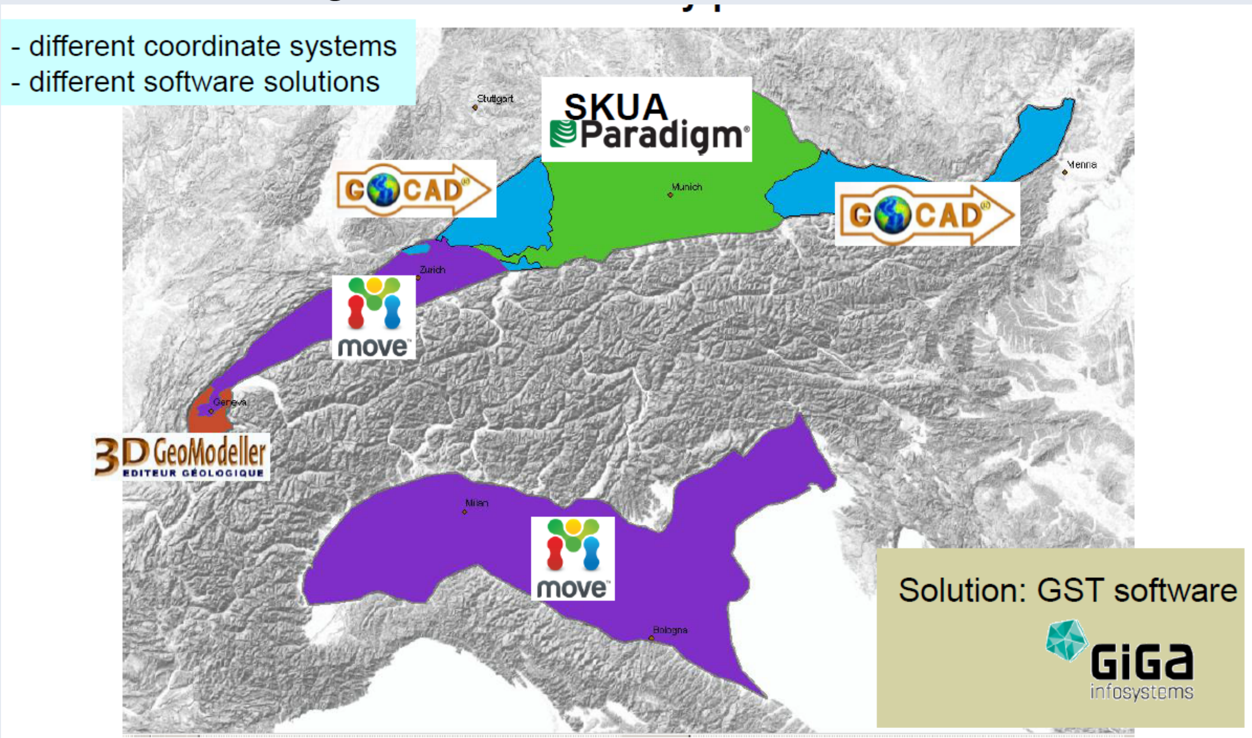
Thematic coverage of study / initiative Please tick topics	x	3D modelling methods with regard to the mapping of utilization potentials and risks
	x	Mapping of potential: open loop systems
	x	Mapping of potential: closed loop systems
		Mapping of land-use conflicts and risks, environmental impact assessment

Shallow geothermal utilization methods covered by project / initiative	Temperature models

Executive summary / synopsis of the report Maximum 1000 characters
Assemblage of a 3D model generated by different states with different softwares Unified workflow for data processing (seismic interpretation, drillings) Harmonized data base with uniform classification of lithostratigraphic units Internal consistency is obtained by the exchange of drilling data Common interpretation and modelling of bordering areas + finetuning Individual geothermal modelling with compöetely different methods

3D modelling software

3D Geomodeller, move, gocad, Skua, GST

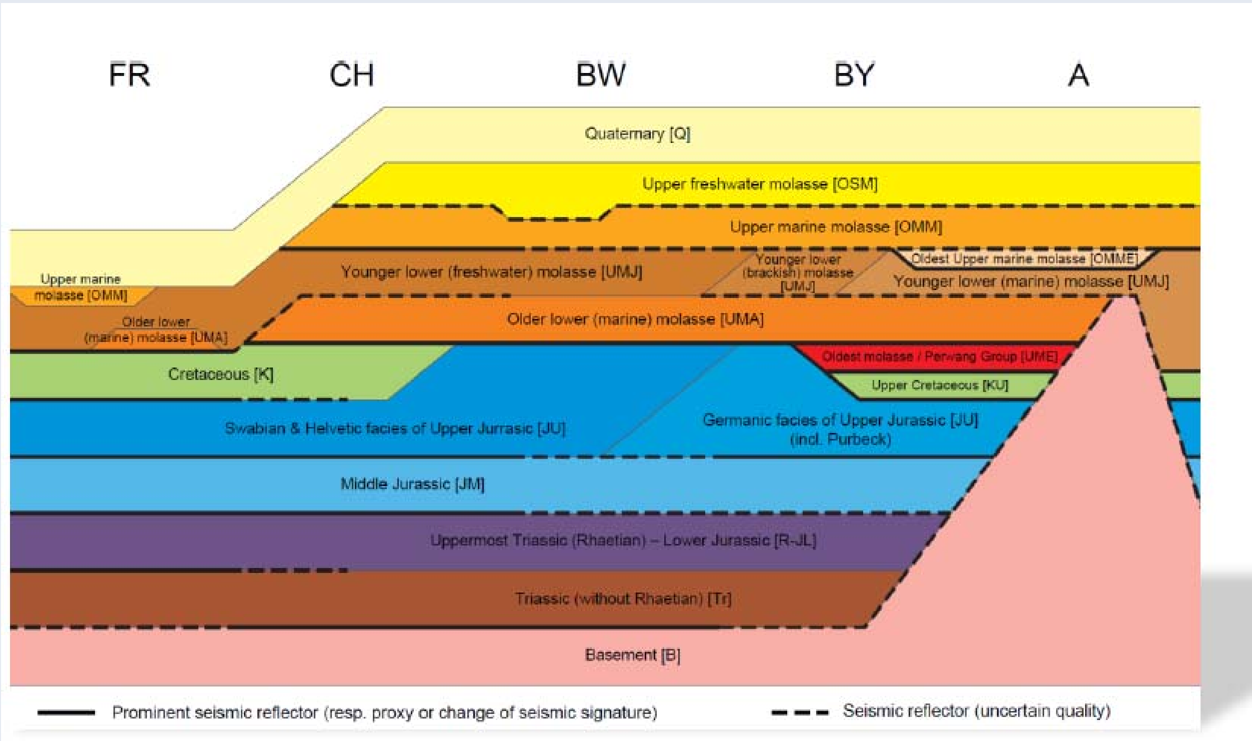


Input data

Drillings, seimic, geological maps, structural data, temperature data

Description of applied approach (methods and workflow)

Harmonized legend



Individual workflows

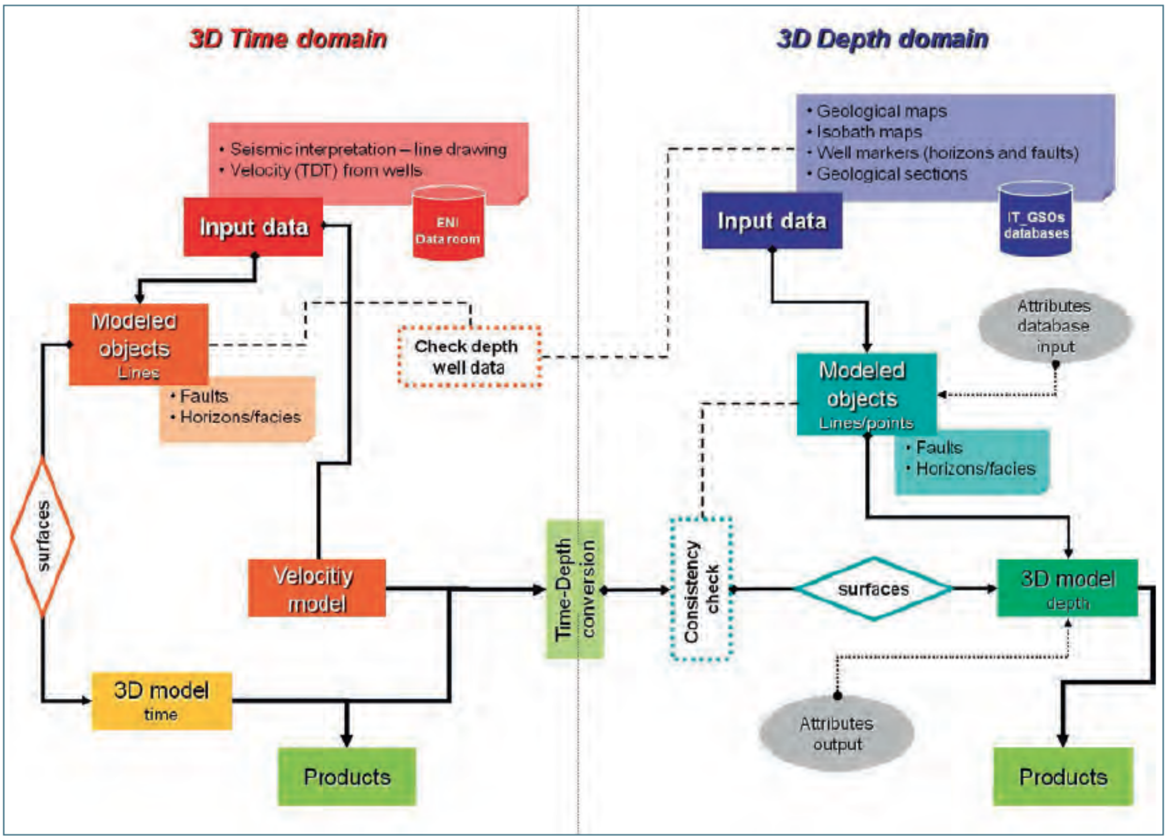


Figure 5.2-1: Schematic diagram of the two basic workflows applied in 3D modelling depending of the kind of data used for model input (from MAESANO et al. 2014). See text for discussion.

Modell parts:
Modelling the fault network
Modelling horizons

All models:
Consistency check
check for horizon crossings with the ground level, and in-spection for horizon crossings and a test for well marker fit.

In Baden-Württemberg and Switzerland framework models and pilot area models are partly based on different input data sets. Hence, a complete consistence between both model types is not possible. Particularly independently constructed fault patterns exhibit differences. On the other hand, the position of horizons and the thicknesses of the geological units have been mutually adopted, so that horizons of both models match each other.

Exchange of well data sets which are close to GeoMol-internal borders, common interpretation of petrographic descriptions and geophysical well measurements
• Agreement on the workflow of technical processing of seismic profiles as well as technical parameters (datum plane, replacement velocities) between partners
• Workshops for seismic interpretation, agreements on picking principles for seismic reflectors, common interpretation of cross-border seismic profiles
• Correlation of cross-border fault systems

Output data
Triangulates surfaces

Advantages
Very flexible and open for all kinds of software
Disadvantages
Modelling results are not directly comparable
Description of the suitability of the chosen approach for GeoPLASMA-CE
Consider harmonization of data preparation

Parameter and potential model

Input data

Software

Output data

Temperatures

Approach/Workflow

Individual modelling of temperatures in separated pilot areas

Area	Involved country	Temperature correction	Temperature modelling	Model calibration, error estimation
Lake Constance – Allgäu Area (LCA) w/o Swiss territories	Baden-Württemberg	None, use of BHT data already corrected (Kühne 2006).	Analytical a-priori model based on regionalised geothermal gradients	Calibration based on residuals
	Bavaria	BHT: inverse and forward correction based on cylindrical heat source.		
	Austria	BHT: *Horner* plot		
Geneva-Savoy Area (GSA)	France	BHT: regionalisation methods (Gable 1978)	Analytical a-priori model based on regionalised geothermal gradients	Calibration based on residuals
Upper Austria – Upper Bavaria Area (UA – UB)	Austria	BHT: inverse optimisation method, cylindrical heat source Outflow temperatures: *Horner* plot	Numerical a-priori model	Calibration and error estimation based on residuals
	Bavaria	BHT: inverse optimisation method, cylindrical heat source	Geo-statistical inter-polation of geothermal gradients	
Brescia-Mantova-Mirandola Area (BMMA)	Italy	BHT: *Horner* plot, *Zschocke* method and regionalisation methods (Pasquale et al. 2008)	Analytical a-priori model based on regionalised geothermal gradients (cf. Molinari et al. 2015)	Calibration based on residuals
Mura-Zala Basin	Slovenia	BHT: *Horner* plot, *Lachenbruch & Brewer* plot	Geo-statistical inter-polation	None

Geothermal potential modelling

Due to the paucity of data hydraulic properties and their spatial variation within modelled units as well as the hydraulic characteristics of the modelled faults could not be differentiated on the assessment of the geothermal potential. These aspects have to be considered in local-scale studies.

Temperature models base on measured subsurface temperatures.

Data processing includes the calculation of the true vertical as well as horizontal position of a single datum point at the subsurface as well as temperature correction. Temperature correction are only applied for BHT measurements as well as outflow temperatures at the wellhead in order to estimate the true formation temperature. All other available temperature sources are either estimated to reflect the true formation temperature (undisturbed temperature logs and DST measurements) or not able to be corrected (disturbed temperature logs). In a next step, the individual datum points may optionally be allocated to geological units in order to allow data filtering. This processing step has been applied for the UA – UB pilot area only. The final step of the data processing consists in a plausibility evaluation in order to eliminate temperature datum points affected by a large error.

Temperature modelling (2D, 3D) has been achieved by either data interpolation or / and forward modelling. Pure data interpolation or extrapolation is only recommendable in case of a sufficiently high density of datum points.In contrast, numerical modelling requires more effort and a conceptional a-priori model, which will be translated into a temperature model. In many cases a combination of both approaches have been applied during GeoMol in order to achieve temperature models.

Model calibration and estimation of error: Temperature models, which rely on any kind of numerical or analytical modelling, need to be calibrated based on processed temperature data.
For that purpose, residuals between modelled and observed temperature values are calculated and superposed to the a-priori model in order to minimise the prediction error at observation points. These residuals, which are often interpolated to a regular grid, also reflect the prediction error of the a-priori model. In contrast, error estimation of data interpolated to a regular grid is reflected by the statistical error of variance associated to the chosen interpolation method (e. g. Kriging).

geopotential map series of the pilot areas and the Mura-Zala Basin:

- temperatures at the top of the most important productive aquifers,
- temperatures at 0.5 km, 1 km, 1.5 km, 2 km, 3 km and 4 km depths below surface,
- depths of the 60 °C, 100 °C and 120 °C or 150 °C isotherms,

each combinable with the distribution of the geological units and the transection traces of the principal faults at the respective depth levels.

Data and workflow harmonisation: Except for the SMA and BMMA, all pilot areas are covering at least two different countries. For that reason, harmonisation of data and workflows has been a crucial issue. Considering the evaluation of the quality of different data sources the quality coefficients proposed by Clauser et al. (2002) have been applied for the pilot areas UA – UB and LCA. These coefficients are a good tool for a harmonised evaluation of the quality of input data and can also be used for the creation of data density maps. However, these quality coefficient do not reflect the quality of the method chosen for BHT correction. As the coefficients are normalised, they may also be used as weighting factors for geo-statistical data interpolation. Data processing was executed individually by all project partners involved at a certain pilot area. At the early stage of data processing the individual methods for data processing have been assessed by questionnaires. The assessment of applied methods show, that in most cases well established, internationally published methods have been applied. Only for datum points having less than two BHT values regionally differing empiric methods have been used for data correction. In most cases these methods are not transferable to other regions as they are only derived from regional datasets.

Analytical as well as numerical a-priori models do not refer to measured subsurface data. For that reason, model calibration based on observation points is inevitable. In addition, the calculated residuals in most cases give valuable information about heat transport processes not included in the a-priori model (e. g. convective heat transport not included in a pure conductive heat transport model) and data errors. For the UA – UB pilot area the calculated residuals have also been used to identify erroneous observation points. In a second stage of quality control, all measured subsurface temperatures showing residuals of more than ± 20 °C have been once again checked for plausibility.

Based on the experiences gained from GeoMol, it is recommended to establish an a-priori temperature model, which is not directly derived from measured subsurface temperatures of varying data quality. A pure conductive numerical 3D model has, in addition, the advantage of allowing hydrogeological interpretation

based on calculated residuals. If an a-priori model is not available for a certain region, it is recommended only to use high quality input data (e. g. quality coefficient referring to Clauser et al. (2002) of at least 0.7) for geo-statistical interpolation. Model calibration and quality checks can later be performed on low quality input data not considered for the interpolation. This approach is of course limited by the spatial density of available high quality input data.
Output data
Advantages
Very flexible and open for all kinds of software
Disadvantages
Results are not comparable
Suitability for Geoplasma
Suggestion for the visualization of temperature maps (depth-levels, temperature-levels, horizons)

Potential maps Input data
Software
Output data
Isopache maps for the bases of stratigraphic units Thickness maps Temperature maps on varius depth level (1000, 1500, 2000, 3000, 4000 m) Depth of 60, 100, 150 °C isotherm Annual heat extraction capacity MWh/a Permanent heat extraction kW
Approach/Workflow
Output data
Advantages
Very flexible and open for all kinds of software
Disadvantages
Results are not comparable
Suitability for Geoplasma
Suggestion for the visualization of temperature maps (depth-levels, temperature-levels, horizons)

GeotIS- geothermal information system of Germany

Please use this sheet for summarizing realized methods and approaches on both national as well as international level. Use one sheet per project / initiative and make sure to upload reports screened for this assessment on the joint knowledge repository, even in case the report is only available in national language!

Please insert information in the blue colored fields.

ID knowledge repository As indicated in register at Own Cloud	25	Reference Please use format: Author, Year, Title, Journal, Publisher	https://www.geotis.de/geotisapp/geotis.php *AGEMAR, T., ALTEN, J., GANZ, B., KUDER, J., KÜHNE, K., SCHUMACHER, S. & SCHULZ, R. (2014): The Geothermal Information System for Germany - GeotIS – ZDGG Band 165 Heft 2, 129–144"* *AGEMAR, T., WEBER, J. & SCHULZ, R. (2014): Deep Geothermal Energy Production in Germany – Energies 2014 Band 7 Heft 7, 4397–4416*

Territorial coverage of study / initiative National – please indicate country; international – please indicate participating countries	Germany, main focus on the North German Basin, Upper rhine graben, south German Molasses Basin

Thematic coverage of study / initiative Please tick topics	x	3D modelling methods with regard to the mapping of utilization potentials and risks
	x	Mapping of potential: open loop systems
		Mapping of potential: closed loop systems
	x	Mapping of land-use conflicts and risks, environmental impact assessment

Shallow geothermal utilization methods covered by project / initiative	3D geological/structural model Deep aquifers Temperature model

Executive summary / synopsis of the report Maximum 1000 characters
3D model of major faults and horizons (TSURFS) Extraction of 2D and unit-wise SGrids Temperature interpolation from measuements in drill holes Heat production capacity or mean power production

3D modelling software
Gocad-Skua
Input data
GeoTectonicAtlas, maps, seismic, contour maps
Description of applied approach (methods and workflow)
3Dmodelling of main horizons and faults →Triangulated surfaces Extraction of 2D grids or of SGrids unitwise-unconnected Generation of a voxet for the temperature simulation
Output data
2D grid: 100 m Voxel: 2000 m horizontal, 100 m vertical
Advantages
2D grid: simple generation of cross-sections, small storage SGrid: representation of complex fault patterns Surfaces and volumina can be parameterized
Disadvantages
2D grid: overturned and thrusted structures get lost during data conversion from TSURF Holes along normal faults Fault geometry is not part of the 2D horizon grids Conversion from TSURF to 2D-grid is necessary No parameterization of the geological bodies is possible→ average for each vertical “line”
Description of the suitability of the chosen approach for GeoPLASMA-CE
Web platform may give ideas

Parameter and potential model Input data
Voxel Temperature measurements from drillings
Software
Gocad-Skua?
Output data
Temperatures
Approach/Workflow
Temperature of the subsurface universal kriging of temperature data
Output data
Advantages
Disadvantages
Suitability for Geoplasma

Suggestion for the visualization of temperature maps (depth-levels, temperature-levels, horizons)

Potential maps Input data
Software
Output data
Isopache maps for the bases of stratigraphic units Thickness maps Temperature maps on varius depth level (1000, 1500, 2000, 3000, 4000 m) Depth of 60, 100, 150 °C isotherm Annual heat extraction capacity MWh/a Permanent heat extraction kW
Approach/Workflow
Output data
Advantages
Very flexible and open for all kinds of software
Disadvantages
Results are not comparable
Suitability for Geoplasma
Suggestion for the visualization of temperature maps (depth-levels, temperature-levels, horizons)

Risk and landuse conflicts Input data
Faults, Salt strucutres
Software
Output data
Map with faults and salt structures not interpreted

Suitability for Geoplasma

ISONG – information system surface near geothermal energy

Please use this sheet for summarizing realized methods and approaches on both national as well as international level. Use one sheet per project / initiative and make sure to upload reports screened for this assessment on the joint knowledge repository, even in case the report is only available in national language!

Please insert information in the blue colored fields.

ID knowledge repository As indicated in register at Own Cloud	26	Reference Please use format: Author, Year, Title, Journal, Publisher	http://isong.lgrb-bw.de/

Territorial coverage of study / initiative National – please indicate country; international – please indicate participating countries	Baden-Württemberg 400 m depth

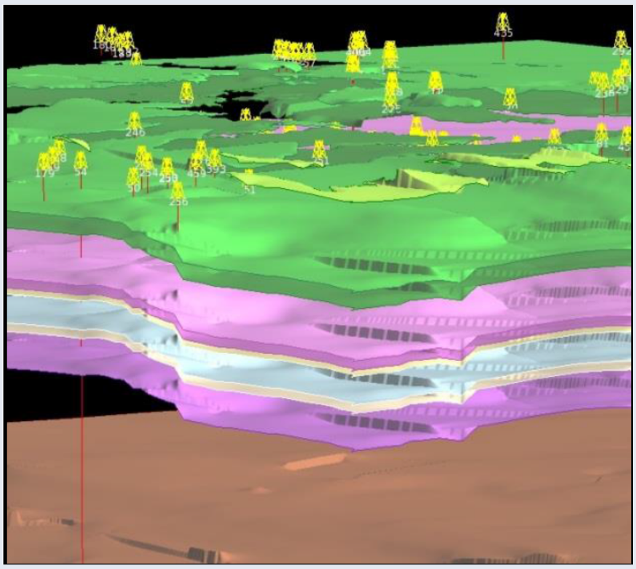
Thematic coverage of study / initiative Please tick topics	x	3D modelling methods with regard to the mapping of utilization potentials and risks
	x	Mapping of potential: open loop systems
	x	Mapping of potential: closed loop systems
	x	Mapping of land-use conflicts and risks, environmental impact assessment

Shallow geothermal utilization methods covered by project / initiative	

Executive summary / synopsis of the report Maximum 1000 characters

3D modelling software
Gocad
Input data
Drillings, geological maps, isopach maps
Description of applied approach (methods and workflow)
3D model of major faults and horizons (TSURFS)

Modelling from DGM Downward
Thickness distributions
Solid from Thickness
Extract TSurf FROM sOLID



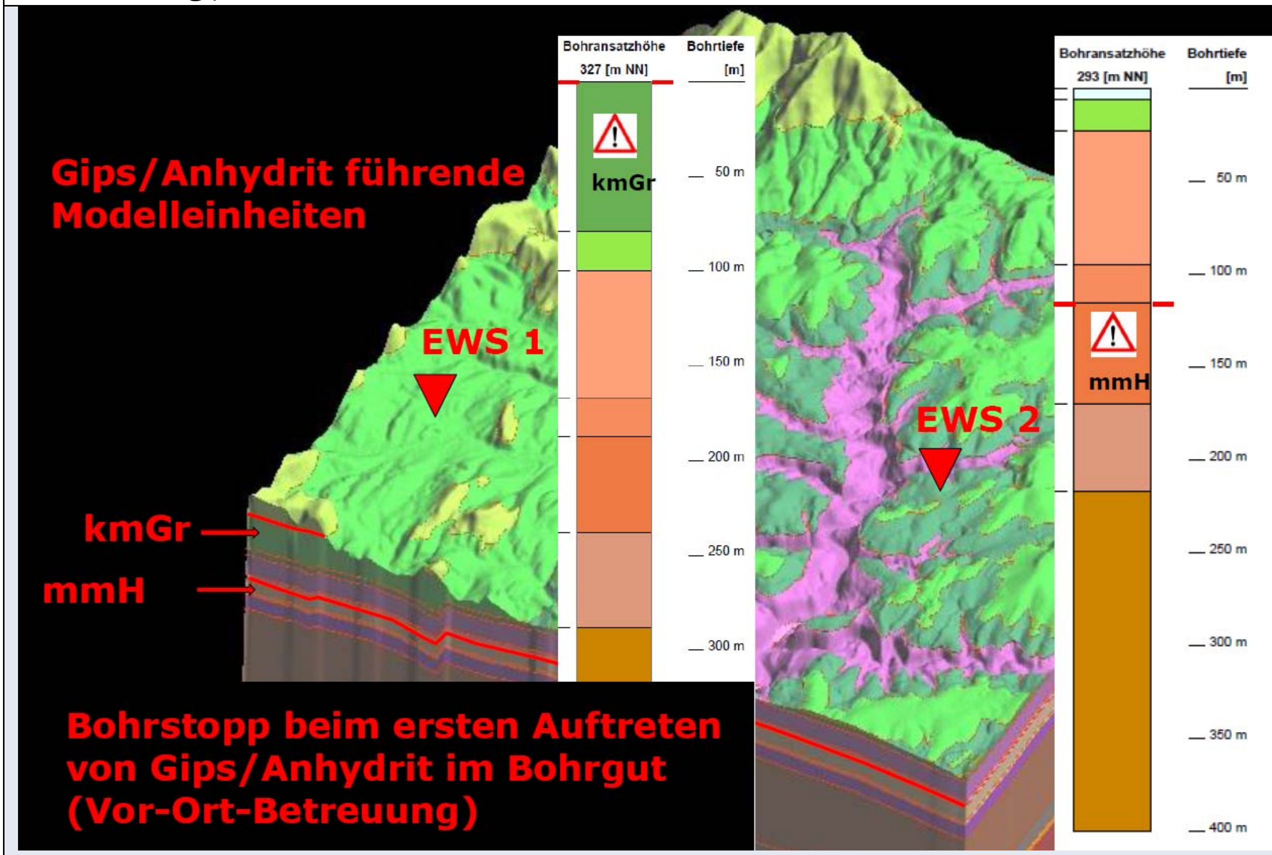
Output data
3D geological/structural model 1:50 000 TSurf horizon base
Advantages
No horizon crossings are possible
Disadvantages
Topography can be seen in the lowest horizons although the morphology of the horizon is not constrained by data
Description of the suitability of the chosen approach for GeoPLASMA-CE

Parameter and potential model Input data
Regionalized geothermal gradients
Software
?
Approach/Workflow
Analytical a-proiri model ? Calibration based on residuals
Output data
heat extraction capacity

Advantages
Disadvantages
Suitability for Geoplasma

potential maps Input data
Software
Output data
Specific heat extraction capacity for houses heating systems working 1800 h/a (only heating) or 2400 h/a (heating and hot water production)
Approach/Workflow
Output data
Advantages
Disadvantages
Suitability for Geoplasma

Conflict maps maps Input data
Maps for protection zones: drinking, mineral and curative water Information from 3D model: limitation of drilling depth (swellable rocks) Artesian springs and aquifers
Software
Output data
Prognostic drilling profile Indicating the geological units, artesic groundwater, swellable rocks, limitation of drilling depth
Approach/Workflow

Output data Virtual drilling profile

Advantages
Disadvantages
Suitability for Geoplasma
Prognostic drilling path for one location with risks

Markovec and Karavanke tunnel 3D

Please use this sheet for summarizing realized methods and approaches on both national as well as international level. Use one sheet per project / initiative and make sure to upload reports screened for this assessment on the joint knowledge repository, even in case the report is only available in national language!

Please insert information in the blue colored fields.

ID knowledge repository As indicated in register at Own Cloud	27	Reference Please use format: Author, Year, Title, Journal, Publisher	Zivec, http://www.3dgeology.org/resources/wiesbaden/ D2_S3_08_3DGM_CivilIndustry_TinaZivec.pdf

Territorial coverage of study / initiative National – please indicate country; international – please indicate participating countries	Slovenia

Thematic coverage of study / initiative Please tick topics	x	3D modelling methods with regard to the mapping of utilization potentials and risks
		Mapping of potential: open loop systems
		Mapping of potential: closed loop systems
		Mapping of land-use conflicts and risks, environmental impact assessment

Shallow geothermal utilization methods covered by project / initiative Please specify systems (e.g. borehole heat exchanger, groundwater well, horizontal collector)	none

Executive summary / synopsis of the report Maximum 1000 characters
Engineering 3d modelling project displaying the fault network and the major geological units along a tunnel

Description of input data used for mapping Please make a general sketch, no detailed data lists (e.g. hydrogeological maps scale 1:50.000)
Geological map, drilling, remote sensing data form the tunnel

Description of applied approach (methods and workflow) for mapping
Leapfrog

Implicit modelling of the fault blocks, veins and metamorphic units Each unit is modelled individually The resulting bodies are cut by Boolean operations the lithology is modelled in each fault block

Description of the output Please make a general sketch, no detailed data lists (e.g. hydrogeological maps scale 1:50.000)
Triangulated surfaces
Description of the suitability of the chosen approach for GeoPLASMA-CE Please write a short review about the pros and cons of the chosen approach! Is that approach suitable for GeoPLASMA-CE?
Consistent model for complex geological situation with faults, veins,...

Geothermieatlas Sachsen

Please use this sheet for summarizing realized methods and approaches on both national as well as international level. Use one sheet per project / initiative and make sure to upload reports screened for this assessment on the joint knowledge repository, even in case the report is only available in national language!

Please insert information in the blue colored fields.

ID knowledge repository As indicated in register at Own Cloud	28	Reference Please use format: Author, Year, Title, Journal, Publisher	Handbuch zur Erstellung von geothermischen Karten auf der Basis eines grenzübergreifenden 3D-Untergrundmodells

Territorial coverage of study / initiative National – please indicate country; international – please indicate participating countries	Region Odra-Neisse in Germany and Poland

Thematic coverage of study / initiative Please tick topics	x	3D modelling methods with regard to the mapping of utilization potentials and risks
		Mapping of potential: open loop systems
	x	Mapping of potential: closed loop systems
		Mapping of land-use conflicts and risks, environmental impact assessment

Shallow geothermal utilization methods covered by project / initiative	Public version for location queries private builders With heat extraction capacity Professional version for planning consultant and drilling companies contains additionally the heat specific conductivity

Executive summary / synopsis of the report Maximum 1000 characters

3D modelling software
ArcGIS, Surpack
Input data
Map data, drillings

Description of applied approach (methods and workflow)
Harmonized legend in a data base+ reference geological sections Rasterization of the map data, lateral size of the boundary surfaces by a "Master grid" which predefines the model points of the 2D grid Buffer zone in the border region → is modelled first and not changed during the later work steps Interpolation of the top horizons with Kriging
Output data
Top horizon, base horizon and thickness, vertical "side" boundaries 2D grid with 25 m stepwidth
Advantages
Disadvantages
Description of the suitability of the chosen approach for GeoPLASMA-CE

Parameter and potential model Input data
3D model →2D grid horizon tops 25 m resolution Groundwater table Specific thermal conductivity for wet and dry rocks on drilling cores
Software
ArcGIS
Approach/Workflow
Load the top horizons for each unit Load the ground water table Distinction of cases for wet and dry rocks → calculate the following for both: Parameterize the drillings with the specific conductivities Average conductivities of one drilling for the whole unit (upscaling) by a depth-weighted mean Assign the weighted mean to the raster cell of the top horizon of each unit Interpolate the specific thermal conductivities with the method of inverse distances Cut the raster according to the groundwater table: if the depth of the top horizon is smaller → assign dry conductivity, if the depth of the top horizon is greater → assign wet conductivity Calculate the specific thermal conductivities for 40, 70, 100, 130 m depth
Output data
25 m 2D Grid with specific heat conduction for 4 depth levels: 40, 70, 100, 130 m
Advantages
Disadvantages
Suitability for Geoplasma

Potential maps Input data
2D grid with specific thermal conductivity and depth of the top horizon
Software
ArcGIS ID Geothermal extension
Approach/Workflow
Calculate the specific heat extraction capacity by a empiric formula using the specific thermal conductivity: Entzugsleistung = -0,96 * λ_2 + 13,00 * λ + 29,60 (for 1800 h/a)
Output data
25 m 2D Grid with specific heat extraction capacity
Advantages
Disadvantages
Suitability for Geoplasma

TUNB – 3D model of the subsurface of the North German Basin

Please use this sheet for summarizing realized methods and approaches on both national as well as international level. Use one sheet per project / initiative and make sure to upload reports screened for this assessment on the joint knowledge repository, even in case the report is only available in national language!

Please insert information in the blue colored fields.

ID knowledge repository As indicated in register at Own Cloud	29	Reference Please use format: Author, Year, Title, Journal, Publisher	Zehner + von Görne, pers. Comm.

Territorial coverage of study / initiative National – please indicate country; international – please indicate participating countries	North Sea, Sachsen-Anhalt. Mecklenburg-Vorpommern, Schleswig-Holstein, Niedersachsen

Thematic coverage of study / initiative Please tick topics	x	3D modelling methods with regard to the mapping of utilization potentials and risks
		Mapping of potential: open loop systems
		Mapping of potential: closed loop systems
		Mapping of land-use conflicts and risks, environmental impact assessment

Shallow geothermal utilization methods covered by project / initiative	

Executive summary / synopsis of the report Maximum 1000 characters
Unified digital subsurface model of the north German basin,

3D modelling software
Skua/Gocad
Input data
Drillings, seismic, geological maps
Description of applied approach (methods and workflow)
Harmonization of the stratigraphic column and workgroup discussing the definition of each

horizon Detail level of faults States exchange data along the boundaries → geometry is conformable along the boundary, topology not Skua structure and stratigraphy or explicit gocad models
Output data
tsurfs
Advantages
One large common model
Disadvantages
Individual modelling workflow for each state
Description of the suitability of the chosen approach for GeoPLASMA-CE
Level of detail for faults