CATALOGUE OF SUCCESS CRITERIA FOR A SUSTAINABLE MANAGEMENT OF SHALLOW GEOTHERMAL USE

Deliverable: D.T2.5.1

Project partner: LP-GBA

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Glossary

A full glossary of terms is available at www.geoplasma-ce.eu

Abbreviations

BHE	Borehole heat exchanger
CLS	Closed-loop system
OLS	Open-loop system
RES	Renewable energy source
SGE	Shallow geothermal energy
SGES	Shallow geothermal energy system
D.TX.Y.n	GeoPLASMA-CE deliverable. The annotation correlates to the according work package (X) and task (Y) and facilitates an easy search for documents on the GeoPLASMA-CE homepage and the web-portal.

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1. INTRODUCTION

Activity A.T2.5: Elaboration of a multilingual catalogue of success criteria for a sustainable management of shallow geothermal use

Description of deliverable D.T2.5.1: Catalogue of success criteria for a sustainable management of shallow geothermal use

"This document represents a summary of all outcomes of TWP2 (English and languages of involved countries) including current policies. It addresses all Central Europe regions and will be published at the project web platform (O.T1.2) for knowledge transfer."

The deliverable is closely related to former deliverables of this activity:

- D.T2.4.1 Summary of national legal requirements, current policies and regulations of shallow geothermal use
- D.T2.4.2 Catalogue of reviewed quality standards, current policies and regulations
- D.T2.4.3 Knowledge exchange workshop on legal requirements, procedures and policies

For further information, we refer to these deliverables on our GeoPLASMA-CE homepage and the GeoPLASMA-CE web-portal.

1.1. The need for a legal framework and technical standards

Shallow Geothermal Energy is a sustainable source of renewable energy and capable of providing base load of thermal energy. Its use is fully aligned with EU energy policy and climate goals. Shallow Geothermal Energy has the potential to become a key technology for the low-emission heating and cooling of individual buildings as well as the supply of heating/cooling grids. Shallow Geothermal Energy can be deployed as an integral part of Smart Grids: As a controllable load, it creates cross-sectorial synergies and supports technologies in the electricity sector. As a relatively new technology, a suitable framework for the utilization of Shallow Geothermal Energy may yet be undefined or underdeveloped. In order to access the economical, ecological and political benefits of Shallow Geothermal Energy, it is of utmost importance to provide a suitable legal and technical framework.

A legal framework especially adapted to SGE will

- Provide legal certainty for all parties involved in the planning, licensing, financing, implementation and operation of a Shallow Geothermal Energy System;
- Provide the basis for a notification scheme or licensing scheme;
- Provide the basis for the collection of data about realized Shallow Geothermal Energy Projects and facilitate the reporting of energy production and climate data.

The publication of technical standards or guidelines will

- Prevent incidents and minimize environmental impact;
- Provide sustainable utilization of SGE;
- Provide quality assurance and improve market acceptance.

Recommendations for the implementation of EU-wide minimum standards are presented in this document.

1.2. GeoPLASMA-CE objectives for the use of geothermal energy

This catalogue represents a summary of all outcomes of the GeoPLASMA-CE activity TWP2: "Elaboration of methodical workflows and transnational standards". This includes assessment and mapping methods as well as standards for planning, construction and monitoring of geothermal sites.

According to the **EU-Directive 2009/28/EC,** Geothermal energy is a renewable energy and part of the measure package needed to reduce greenhouse gas emissions and to comply with the Kyoto Protocol on Climate Change. It fosters decentralized energy production and thus the utilization of local energy sources, increases local security of energy supply, shortens transport distances and reduces energy transmission losses.

Deploying geothermal energy requires activities intruding into the subsurface. This means that geothermal energy installations, such as wells or borehole heat exchangers, become a part of the environment and thus a part of the subsurface infrastructure like underground pipes or cellars are. In addition, the use of thermal energy results in seasonal or permanent temperature changes in the subsurface. These changes can affect economic and social interests and must be considered while planning geothermal installations. The impact of an individual installation onto the subsurface temperature distribution can be of positive or negative nature. It is considered negative if the impact of neighboring installation adds up and positive if the individual temperature changes partially cancel each other out. The latter occurs when heating and cooling happens simultaneously in the same zone of influence, e.g. in industrial areas where process heat is generated, or in livestock farming. The use of thermal energy technologies in smart grids can lead to an effective utilization of heat sources and heat sinks. Moreover, geothermal energy and its capability for cooling can be a remedy to anthropogenic warming of the underground occurring in cities.

A careful, **precautionary** management of this resource guarantees a **sustainable**, **renewable, climate friendly** and **efficient** use and ensures deploying the full potential of geothermal energy. This includes knowledge about the potential of shallow geothermal energy, the knowledge of existing installations, a legal framework providing quality standards for the implementation of geothermal energy systems and trained staff.

Throughout the entire project duration, the GeoPLASMA-CE team worked on management structures ensuring an optimal use of shallow geothermal energy. Results are processed as **success criteria and quality standards**.

The presented recommendations and tools are intended to support the improvement of existing management strategies and the development of new strategies with the aim of **simplification** and **harmonization**. Recommendations and tools were designed to be adaptable to existing legal frameworks, allowing their use everywhere around the world.

- **Simplification** is achieved by providing tools, like geothermal registers, geothermal potential maps or conflict maps. These tools facilitate procedures like planning or licensing.
- **Harmonization** aims to align procedures and processes in different regions or countries while allowing them to adapt to local conditions.

The expertise within the project is strongly focused on specific geoscientific areas. Political and economic aspects will therefore not be considered within this report. Nevertheless, in general we present ideas and possibilities that can be independently adapted to the present management of SGES. Every step towards simplification, harmonisation and efficient use is a step to foster shallow geothermal energy and thus to contribute to environment- and climate protection. Regarding quality standards, the expertise lies also in the geoscientific field. Constructional and technical parameters concerning heat pumps, materials or working fluids are mentioned but not evaluated. For information, we refer to existing standards (see ANNEX 2).

GeoPLASMA-CE aims for a sustainable, renewable, climate friendly and efficient use of shallow geothermal energy.

Success criteria measure the achievement of the management objectives for the use of shallow geothermal energy.

Quality standards ensure an efficient und sustainable use of shallow geothermal energy.

2. Management of shallow geothermal energy systems

In present days, the use of most geothermal energy systems is unbalanced, which means the temperature changes in the subsurface are of permanent nature. In combination with the common licensing practice (see GeoPLASMA-CE deliverable D.T2.4.2) in Central Europe this leads to a "first come - first serve" practice where the full potential for the use of geothermal energy is not achieved. Regulations that prevent an unsustainable exploitation of this resource and instead foster measures that ensure an efficient use with respect to space and time are needed for geothermal energy.

The following list summarizes the most important objectives of a fully developed management system:

- Minimizing the impact of shallow geothermal energy use on the subsurface to prevent negative cumulative interaction effects
- Avoiding technical risks and environmental hazards during the installation and operation of shallow geothermal energy systems
- Ensuring health and safety of inhabitants as well as the integrity of existing infrastructure during the installation of the system
- Enhancing and sustaining the efficiency of shallow geothermal energy use
- Ensuring continuous access to information regarding resources and limitations of use (possible conflicts) associated with shallow geothermal energy use
- Accelerating and simplifying licensing and communication routines between regulators and operators / applicants
- Minimizing the costs for both regulators and operators for fulfilling the management concept

An appropriate, integrative management of shallow geothermal energy systems can be a regulative instrument to simplify the implementation of future systems and additionally enhance their efficiency and sustainability.

ANNEX 1 – "GeoPLASMA-CE-Self-assessment sheets" – help to evaluate the current status of SGE and provides pointers for a sustainable and efficient management of SGES.

2.1. Management approach

The GeoPLASMA-CE management approach includes:

- Cyclic management
- Completeness of information
- Digital management
- Integrative management
- Clear responsibilities

While digital management and clear responsibilities in the first place facilitate the management of SGES, all other points are crucial for the realisation of a sustainable, renewable, climate friendly and efficient management of SGES. In this context, GeoPLASMA-CE strongly recommends a **mandatory licencing duty for all SGES** independent of size and use and a binding monitoring.

The GeoPLASMA-CE management approach aims to facilitate the implementation for users as well as for administrative bodies. The management approach is based on five essential principles:

1. **Cyclic management**

Cyclic management is the most important principle for the management of SGES. The GeoPLASMA-CE management loop (Figure 1) symbolizes this principle. It provides a continuous information flow between authorities and users to grant optimized access to information and to update this information.

The loop combines the main stages for the implementation of SGES. This means the binding integration of monitoring measures and the provision of information systems into the management of SGES. Planning, licencing, installation and operation are like a process chain, which is detected as the current management approach in Central Europe. The integration of monitoring and information systems closes this chain to a loop.

Monitoring will provide in situ data, which should be administrated in public information systems. It is then available to planners and provides input for the design of further installations. Monitoring and feedback enable to optimize the system efficiency, to plan future installations and to monitor environmental impacts and ensure an integrated approach for the management of shallow geothermal energy. With information systems also acting as catalogues for existing SGES, planned shallow geothermal usages do profit from previous experiences.

The structure of the GeoPLASMA-CE management loop is primary designed to facilitate integrative management plans, but should be adapted to single use installation too, if management plans are absent.

The management loop related to the regulation and management of shallow geothermal use deals with various technical topics. Most of them can be grouped to two or more work steps of the management loop. The GeoPLASMA-CE-team discusses these topics in Chapter 3 of this catalogue.

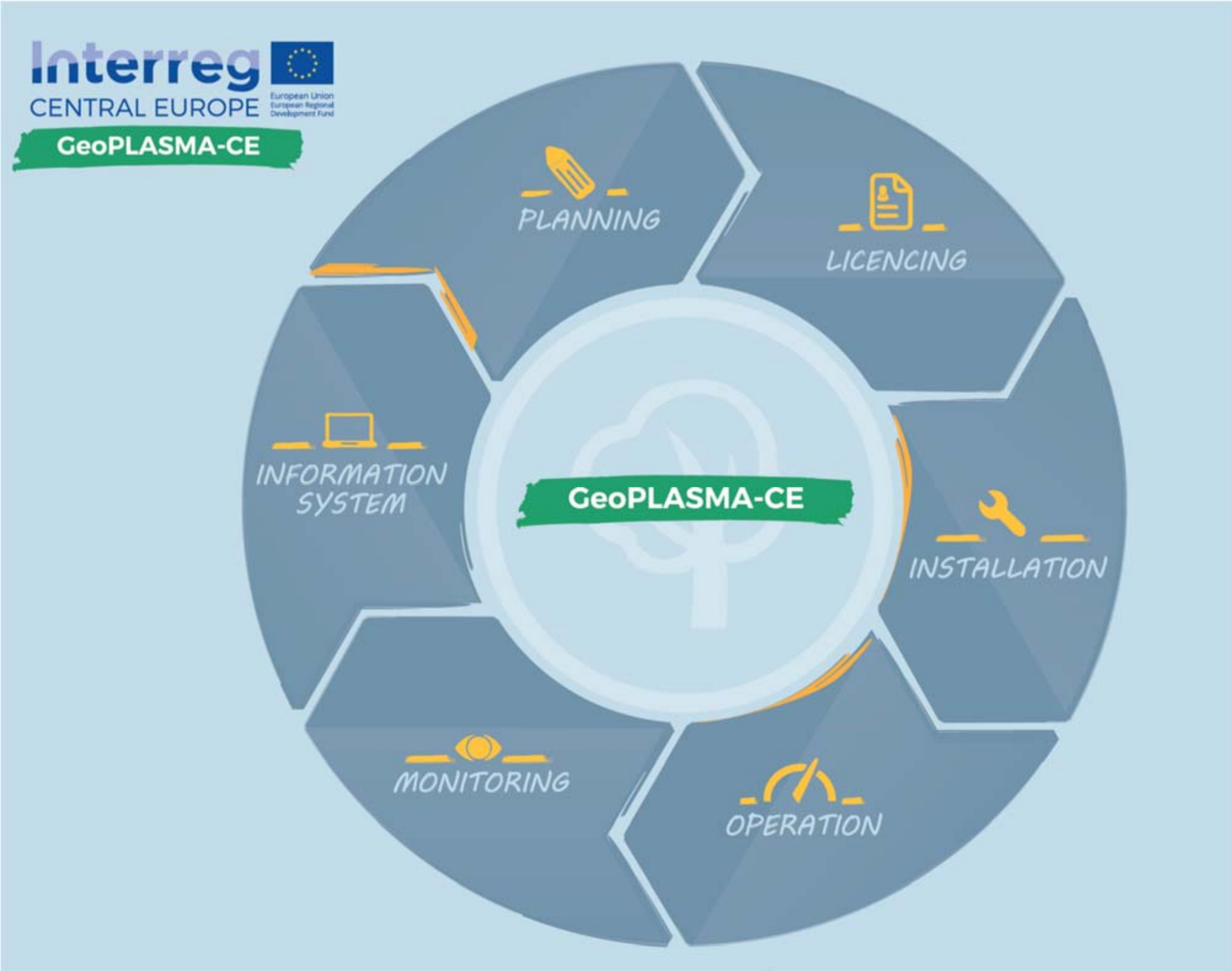


Figure 1: The GeoPLASMA-CE process loop for an integrated approach for the management of shallow geothermal energy systems.

2. Completeness

Present regulations evaluate installations individually or, at most, include only installations in the near vicinity rather than consider them as part of the subsurface infrastructure. This leads also to a non-permitting policy in some countries where smaller installations do not even need a notification to the authorities. A complete knowledge of existing SGES is therefore not only a prerequisite for integrative management approaches; it is in general a necessity to avoid conflicts between individual installations.

3. Digital management

Support web based information and e-government systems to facilitate access to information and communication between users and regulators. Support open data access policies.

4. Integrative management

Includes summation effects and conflicts of use into regional management and supports local energy management plans. Integrative management depends on information. Point 1: Cyclic management and Point 2: Completeness are indispensable prerequisites for an integrative management.

5. Clear responsibilities

Procedures (e.g. application process) should clearly define the tasks of users and administrative bodies. Responsibilities of the different authorities have to be unambiguous concerning their rights and duties, e.g. which authority issues recommendations and which authority may impose binding conditions.

3. Success criteria for the management of SGES

3.1. Planning/Design

Shallow geothermal energy installations have to be designed within the legal framework and under consideration of all applicable quality standards according to the state of the art (ANNEX 2). As pointed out in D.T2.4.2, the legal requirements and technical standards differ significantly between GeoPLASMA-CE partner countries. In addition, the execution of planning is regulated individually in the GeoPLASMA-CE countries. In many countries, the profession of SGE designer is not legally protected and can be practiced without formal certification, or planning and design is part of the installer strategy or heat pump vendor. In this case, GeoPLASMA-CE highly recommends the implementation of standardized certificates for planners respectively designers of SGES. A shallow geothermal energy installation relies on information regarding the geology, hydrogeology, geothermal potential and land-use conflicts. Based on legal framework, technical standards and local conditions, the appropriate SGE system and design is selected. The following list displays the recommended minimum content of considerations concerning the application of SGES. National requirements should be considered in combination with this list.

- **General information** about the building project
- **Geological and hydrogeological information** about the site location
- **Conflict information** about the site location (e.g. neighbouring rights and usages)
- **Design information** (concerning the design in the context of geological, hydrogeological and conflict situation e.g. numerical simulation or analytical calculations)
- **Technical information** (about the heat pump, used materials and fluids as well as information about the planned drilling)

Appropriate geoscientific and conflict data of sufficient quality and coverage should be provided free of charge in a suitable, easily accessible form. Nonexistent data or data of insufficient quality must be compensated by investigations of the planner/designer of the SGES. In this context the importance of the qualification of the executing planner/designer and of the recommended standardized certificates, have to be pointed out again.

Planning/Designing must produce a precise and clear way to install and operate an SGES. Used and generated data as well as calculations or simulations must be comprehensible. The design of SGE is the basis for a sustainable, renewable, climate friendly and efficient SGES. Therefore planning/designing should be a legally certified profession.

ANNEX 3 – "GeoPLASMA-CE – Technical quality standards: A guide for planning and licencing" – helps to determine the minimum requirements for technical quality standards.

3.2. Licensing

In 2009, the European Union issued the European Renewable Energy Directive "2009/28/EC on the promotion of the use of energy from renewable sources" (OJ L 140, 5.6.2009). The Directive includes several measures created to foster and facilitate the use of renewable energies in general.

In order to reduce administrative barriers and enhance future methods for licensing procedures, the directive dictates six general measures that should be implemented into the administrative procedures for renewable energy systems by EU member states.

GeoPLASMA-CE established a licencing scheme (Figure 2) that considers these six EU-measures and adapts them directly for the needs and conditions given by geothermal energy. The scheme focuses on the facilitation for users and allows authorities to act within the national legal framework.

Licencing procedures for users should be independent of installation type and size. Administrative procedures should distinguish between small-, medium and large-scale installations and not between closed- and open loop systems.

A distinction between notification and a full licensing procedure is not useful and bears the risk of confusion and exceptions. Facilitation should be decided during the administrative part of the licencing procedure. In this sense, it is mentioned again that a licencing procedure must be mandatory for all SGES, independent of their size and use.

1. **One-stop shop**

One-stop shop means that there is one responsible authority for the execution of the licensing procedure. This means for the applicant that only one single authority has to be notified or applied to. Applicants should be able to identify the responsible authority easily. Implementation of a one-stop shop procedure is a facilitation for installation of all types and sizes.

2. **Online application**

Online application can be introduced by an e-government system that allows easy communication between user and licensing authority.

3. **Maximum time limit for procedures** and
4. **Automatic permission after deadline passed**

Maximum time limits for procedures should act as a facilitation for their overall construction project. If the official permission is not given within this time span, the EU-measures suggest an automatic permission. Experience shows that time spans can differ depending on the size of the installation and external conditions. The evaluation of a large-scale installation will definitely take more time than the evaluation of a small-scale installation. Nevertheless, the evaluation of a geothermal energy project and the determination of monitoring actions are essential for both cases since a geothermal energy system has environmental impacts. The specification of a maximum time limit by the authority as a first step during a licencing procedure guarantees the evaluation of the project in a user-friendly way.

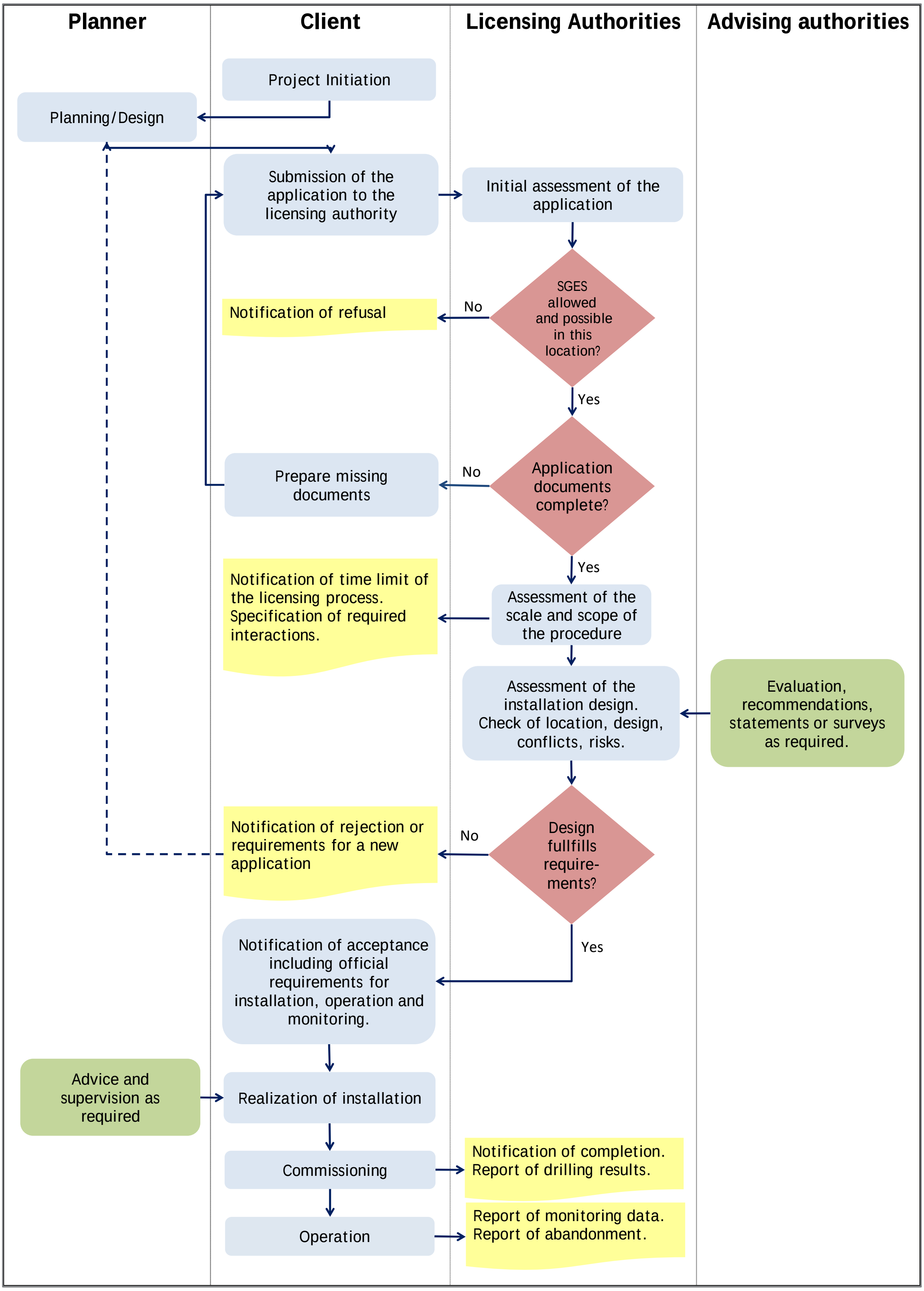


Figure 2: GeoPLASMA-CE licencing scheme

5. Facilitated procedures for small-scale projects

A distinction between the installation sizes for the starting point of the application is not necessary. Official requirements have to be adapted during licencing procedure referring to the needs with regard to the installation size. Table 3 summarises size-relevant requirements for SGES according to their power output.

6. Identification of geographic sites suitable for the exploitation of renewable energy sources

Identification of priority areas helps during the planning of renewable energy systems. GeoPLASMA-CE supports the idea with the inclusion of information systems into the management of renewable energies. Chapter 3.6 focuses on this information system implemented for SGE.

The notification of acceptance must include the official instructions for the installation, operation and monitoring of the installation and respective time spans for the execution. It is advisable to state fixed seasonal balances and the operational mode (including heat extraction rates, water consent and type of use i.e. heating/cooling/seasonal) in the notification documents. Those parameters are indispensable for an integrative management.

3.3. Installation

The installation phase encompasses the implementation and commissioning of an SGE system, including drilling, pumping tests, thermal response tests (TRT), well completion, pressure testing, connection to the heat pump, adjustment of operation parameters etc. up to the final inspection. The correct execution of the installation is defined during planning and confirmed during licensing.

Prerequisite for safe drilling activities is access to information regarding the geological and hydrogeological conditions of the subsurface and in particular of any drilling hazards associated with the location (see chapter 3.4 and ANNEX 4).

Each step has to be performed to a high standard of quality since issues related to the installation phase are usually very hard to rectify, and therefore expensive and time-consuming. Certification of personnel as well as site inspections by the authorities should ensure compliance with proposed projects, technical standards and legal regulations. Please refer to the individual chapters for more information. Further information regarding the acquisition and storage of data can be found in (see chapter 4.6).

It should be mandatory to document the entire drilling, implementation and commissioning stages for legal and quality assurance reasons. The required parameters should be specified and a form should be made available for providing the required information to the authorities.

If a licensed installation is not implemented for any reason, the authorities should be notified.

3.3.1. Abandonment

If an SGE installation is permanently taken out of service, it will have an impact on subsurface conditions. This applies to temperature distribution and, in case of OLS on groundwater levels in the near vicinity. Abandonment of shallow geothermal energy systems needs legally binding requirements and a notification to the responsible authority. Information should be used for planned and future installations as well as scheduling environmental impact monitoring.

Abandonment procedures have to be standardised. For OLS, conversion into an observation well should be considered or filling the well in a way preventing groundwater body contamination. It is recommended that standards deal with the removal of surface equipment such as well head, tubing etc., and with securing the well location. The heat carrier fluid of CLS should be replaced and tubes closed with e.g. cement to prevent adverse impact on ground water and avoid the formation of subsurface cavities (empty pipes).

Abandonment of an installation has to be notified to the authorities.

3.4. Operation

The best operation mode under certain conditions is compiled during planning and stated in the permit. The section "operation of the management loop" covers parameters like the compliance of the permitted peak- and base load, compliance of water extraction rates or technical parameters like temperature ranges (see also chapter 3.3). It is the installer´s and as well as the user's responsibility, to comply with the legal regulations and the stipulations specified in the permit and also to fulfil regular service and maintenance.

Authorities should verify compliance and enforce it with appropriate measures (e.g. environmental monitoring, see chapter 4.6). Installation efficiency can be optimized by performing system efficiency monitoring (see chapter 4.6).

Once commissioned and in operation, heat pumps are relatively low maintenance compared to combustion systems such as oil or gas boilers. Nevertheless, they also benefit from regular maintenance, as this ensures a safe operation and a long lifetime of the installation.

Planning and the according operation of an SGES must focus on an efficient and sustainable use. System efficiency monitoring is a good tool to optimize efficiency.

Regular service intervals and maintenance tasks, similar to those of gas boilers, should be defined and recommended to owners of SGE installations. Maintenance should at least include:

- Visual inspection for wear of mechanical parts
- Measurement of working pressures in all fluid-filled lines
- Check for presence of trapped air or contaminants in the fluid system
- Verification of correct antifreeze concentration (if applicable)
- Measurement and adjustment of volume flow

It should be mandatory to report leakage of heat-carrier fluids from closed-loop systems to the authorities. This obligation of the owner and the correct local contact details of the authorities should be stated in the permit.

3.5. Monitoring

In the SGE sector, the term monitoring denotes the long-term observation of a shallow geothermal installation and/or the subsurface in its vicinity.

Monitoring of shallow geothermal installations helps to achieve the following goals:

- System optimization, i.e. tracking of the individual installations operating parameters or arrays
- Environmental impact assessment, i.e. observation of the subsurface conditions close to the installation in order to identify and quantify changes in quality (in particular regarding groundwater quality)

Monitoring therefore offers benefit to the owners of installations, the authorities and the public.

There are currently no binding regulations regarding the monitoring of shallow geothermal installations in any of the GeoPLASMA-CE partner countries. During the licensing process, the local authorities may mandate monitoring. The particular conditions that trigger a requirement for monitoring, as well as the individual stipulations themselves, are based on case-by-case decisions. These decisions may be up to the discretion of a single person within the licensing process and, in the absence of guidelines, can reflect the knowledge and attitude of individual persons.

The operation of a small installation serving a single-family home and a large system supporting a heating grid or business park differs significantly. Consequently, their requirements regarding both system efficiency monitoring and environmental impact will not be the same. Similarly, open-loop systems and closed-loop systems are based on different principles and require different monitoring regimes.

The goal and scope of monitoring activities should be defined accordingly.

GeoPLASMA-CE recommends the elaboration of firm guidelines, which advise local authorities on:

- Certain circumstances in which monitoring is to be mandated
- The extent of monitoring (parameters, intervals, time period) to be mandated, under consideration of installation size, installation type, environmental setting and potential impact
- Criteria for extension of existing shallow geothermal installation licenses

GeoPLASMA-CE recommends grouping shallow geothermal systems into six categories distinguished by installed capacity and installation type (see Table 1 and 2).

GeoPLASMA-CE recommends that under normal circumstances (i.e. in the absence of pre-defined, specific concerns or adverse conditions), monitoring of closed-loop systems is performed on a voluntary basis irrespective of installation size.

3.5.1. System efficiency monitoring

System efficiency monitoring tracks the installation’s operating parameters, and this data can be used to optimize the installation’s efficiency. Measurement intervals for system-efficiency monitoring depend on the individual parameters and should be chosen carefully. If the interval is too small, large amounts of data will be recorded (storage space, processing time). If the interval is too large, the data will not be representative.

System efficiency monitoring should be performed for a minimum of three years.

Table 1: Extent of system efficiency monitoring. Bold and italic text: Should be mandatory, normal text: should be voluntary. See ANNEX 5 or Glossary for explanations of technical terms.

System efficiency monitoring - at the installation - by the owner			
	S	**M**	**L**
CLS	Analog electricity meter Operating hours Operating pressure	Electronic electricity meter Flow meter (volume flow) Operating pressure	Full monitoring system Operating pressure
OLS	*Initial water analysis* Bi-annual water analysis Analog electricity meter Operating hours	*Initial water analysis* Bi-annual water analysis Mass flow Electronic electricity meter	*Initial water analysis* Bi-annual water analysis Mass flow Full monitoring system

3.5.2. Environmental impact monitoring

Environmental impact monitoring observes parameters relating to the subsurface. This data can be used to identify and quantify:

- Changes to the environment, in particular to the groundwater quality
- Impact on neighbouring installations

Environmental impact monitoring can only be performed if a cadastre of existing installations is available, i.e. if a notification scheme or licensing system is in place which demands completeness of registration (see chapter 2) and also covers decommissioning. Environmental impact monitoring requires access to suitable observation wells. Important aspects defining suitability are: position in relation to the installation, depth, completion scheme and access rights.

A binding definition of "suitable observation well" should be established. The definition should consider the differences between open-loop systems and closed-loop systems as well as the size of the installation.

Environmental impact monitoring should preferentially utilize the existing (public) network of groundwater observation wells. Guidelines should detail appropriate actions to address the absence of suitable observation wells (e.g. cost allocation for new observation wells, responsibility and timeframe for the installation of a new observation well).

As a minimum requirement for environmental impact monitoring of closed-loop and open-loop systems, GeoPLASMA-CE recommends one downstream observation well which covers at least the depth of the top aquifer. For large open-loop systems, the placement of a second, upstream observation well is recommended.

Independent third parties or the local authorities should perform the collection and interpretation of environmental monitoring data. Information flow to the responsible authority has to be ensured.

Environmental impact monitoring should be performed regularly until the installation is decommissioned.

Table 2: Extent of environmental monitoring. Bold and italic text: Should be mandatory, normal text: should be voluntary. See ANNEX 5 or Glossary for explanations of technical terms.

Environmental monitoring - at suitable observation wells - by authorities			
	S	**M**	**L**
CLS	2-4 temp profiles per year	2-4 temp profiles per year	2-4 temp profiles per year
OLS	*Annual volume pumped* *Temp out* *Temp in* 2-4 temp profiles per year	*Annual volume pumped* *Temp out* *Temp in* 2-4 temp profiles per year	*Annual volume pumped* *Temp out* *Temp in* 2-4 temp profiles per year upstream & downstream

3.6. Information system

Planning, designing and permitting an efficient SGE installation in a safe manner requires comprehensive information regarding:

- Scientific description of the subsurface, e.g. rock parameters or groundwater temperatures
- Legal and spatial planning considerations, e.g. compulsory district heating or water protection zones

Currently, there are no standards or guidelines, which cover the provision of such data in a single, publicly accessible information system. Consequently, availability, contents and visualization of data in information systems differ significantly not only from country to country but also between regions or even districts.

Regarding the acquisition, processing and inclusion of data into an information system, access rights can categorize the data:

- **Public information**, such as geoscientific and spatial planning maps
- Usually **restricted information** regarding the location and operating parameters of existing geothermal installations

An information system with a simple structure and unrestricted public access is only possible if all data sources are publicly available. The inclusion of data with restricted access rights automatically necessitates the implementation of a more complicated structure with several tiers of access (e.g. restricting such data for internal use of the authorities).

Aside from the contents themselves, many different aspects relating to user friendliness and service quality determine whether the information system will be widely accepted and utilized. The institution managing the information system can influence most of these aspects.

The bulk of the **publicly accessible information** will consist of maps and environmental monitoring (time series) data owned by the authorities. However, other unrestricted contents could be included or linked to the information system as required, e.g. explanation of the application/notification scheme, relevant contact details ("Yellow Pages"), technical guidelines, best practice examples, links to relevant standards and legal regulations and other information associated with shallow geothermal energy use.

Management and provision of **restricted information** is resource intensive. Including privately owned data into an information system raises many issues related to access and usage rights, accuracy of obtained data, data collection, data transfer, responsibilities, etc. These issues are discussed in deliverable D.T2.4.2 *Catalogue of reviewed quality standards, current policies and regulations*. Since the implementation is largely dependent on the specific legal situation in each country, any possible solution to these issues will not be easily transferrable to other geographic areas.

GeoPLASMA-CE supports open access to data, if individual data protection rights are not breached.

Geoscientific and spatial planning information relevant for SGE installations should be compiled and made accessible free of charge via a single, user-friendly web portal.

The structure of thematic topics should be intuitive and not contain too many levels of hierarchy. It should be clearly visible if a data layer is relevant to open-loop systems, closed-loop systems, or both.

Data has to be factually correct and current. Contents should be revised in regular intervals specified for each individual data set depending on its time sensitivity.

The information system should allow the execution of location-specific queries.

The user interface should be regularly maintained, reflect current practices and be compatible with new browser versions to ensure user friendliness, accessibility and protection against misuse.

It is recommended to include installation-specific data into the information system under consideration of existing legislation, in particular data protection rights.

Access levels should be defined in compliance with national regulations, in particular concerning data protection. A system for user registration and identification should be implemented. Restricted data should be provided upon request and limited in extent to those persons who demonstrate a vested interest.

Unauthorized access to restricted data must be prevented by suitable data storage structures and other security measures.

Restricted data should be made easily accessible to the licensing authorities.

The information system should be linked to an online application system.

GeoPLASMA-CE recommends the inclusion of thematic maps that cover all relevant aspects of geothermal resources, drilling hazards and potential land-use conflicts.

It is recommended to provide depth or time series data originating from observation wells in appropriate graphical form, in particular groundwater levels, groundwater temperature profiles and groundwater analyses.

Data about existing but unregistered or unlicensed installations should be obtained in an appropriate way.

Appropriate tools for capturing digital data should be provided. Utilization of data loggers with automatic data transmission should be enabled.

Data acquisition by trained personnel should be considered in countries where annual emission analyses by a chimney sweeps are well established and widely accepted by the population.

4. Quality standards for the management of shallow geothermal energy systems

Success criteria determine the achievement of the management objectives (see list in chapter 2) for the use of shallow geothermal energy. Whether a shallow geothermal energy project is successful or not depends on internal and external influence factors. Internal influence factors cover aspects, controllable or modifiable by the parties involved in the design and realization, like installation design, choice of material and methods, and the intention to comply with all regulations and adhere to high quality standards. The latter point is of particular importance in countries where quality standards for shallow geothermal energy installations are absent or where the standards are low.

Quality standards must cover:

- The application of state of the art procedures for planning, installing, operating and monitoring of shallow geothermal energy use
- Technical standards including the application or provision of tools and knowledge referring to the state of the art
- Fulfilling of specifications to ensure a safe and low environmental impact operation of shallow geothermal systems
- The definition of quality control measures
- The definition of key terms

A legally binding status for these documents must be mandatory since this guarantees compliance. Moreover, such defined quality standards are valid for the whole country and are a big step towards harmonization.

Parties involved in design and realization cannot influence external influence factors. Examples for external influence factors are the political will of introducing binding management routines by decision makers, the general market situation and energy prices, geothermal potential at the chosen location, and already existing technical standards. External influence factors are not considered in this document. The outputs of GeoPLASMA-CE work package 4, in particular deliverable D.T4.1.2 *Draft strategies for the use of shallow geothermal energy in the investigated target regions and cities* and deliverable D.T4.4.1 *Strategy report for future energy planning and management concepts to foster the use of shallow geothermal methods*, touch some external factors.

Legislation should provide regulations on procedures, quality standards and thresholds. Technical standards should not be laid down in legal regulations directly. However, legal regulations should specify which documents are considered state of the art. These documents are thus legally binding but bear the advantage that they can be adjusted more easily and quickly than legislation, i.e. they can be updated regularly to reflect advancements in technology and knowledge.

The quality standards provided in GeoPLASMA-CE mostly refer to more than one cornerstone of the proposed GeoPLASMA-CE management loop. As mentioned in chapter 2.2, the cornerstones of the management loop share the same topics but are executed by different parties. In the following subchapters, quality standards are covered in a general way.

4.1. Definitions

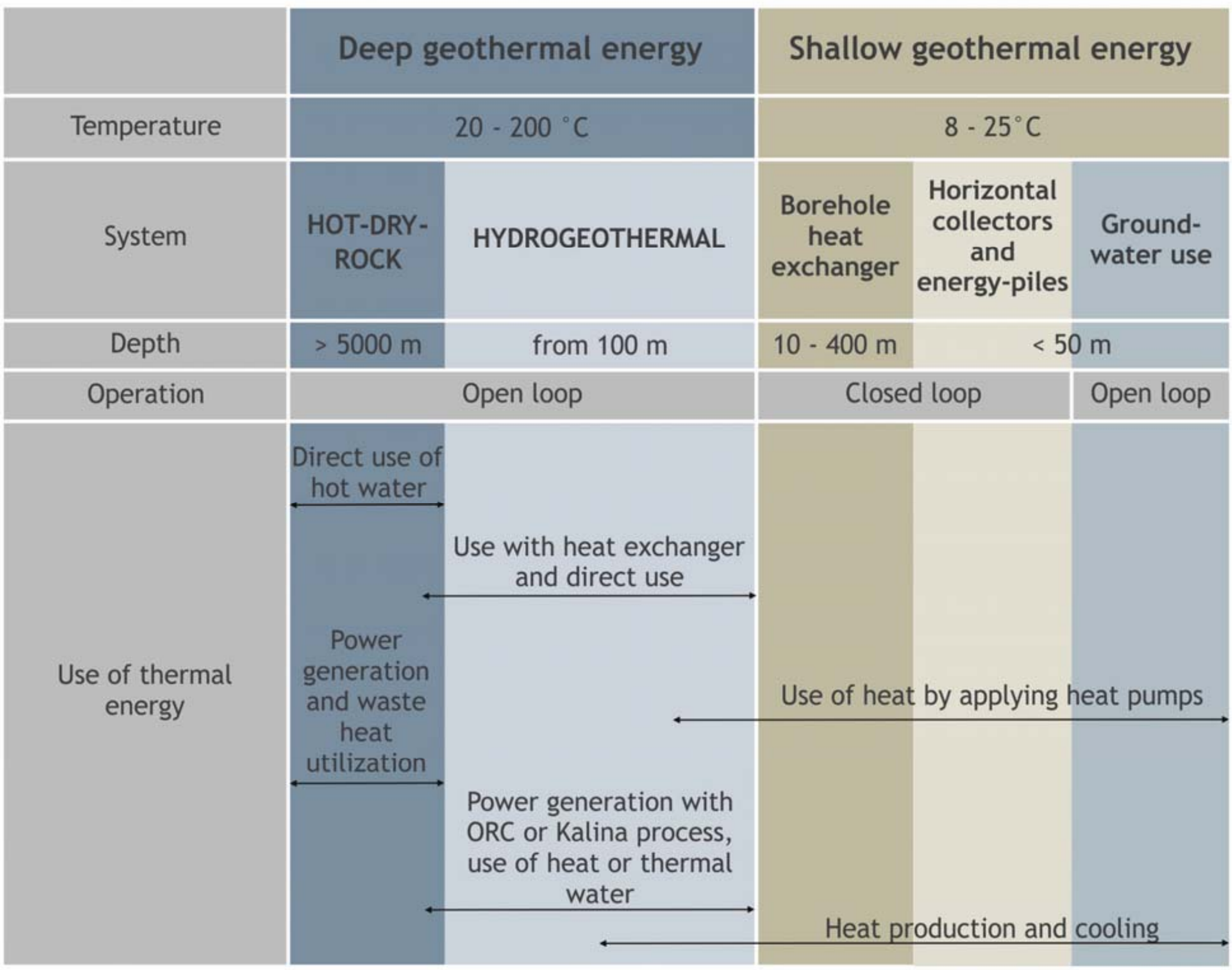
Definitions are crucial to ensure that everyone shares some basic understanding when talking about shallow geothermal energy use - especially as member countries of the European Union with the same legal framework and aims. Although a common definition within the European Union would be favourable, the definition of key terms should be at least clear and strongly stated for each country. Within the GeoPLASMA-CE project, three main key terms were identified that require a definition.

4.1.1. Shallow geothermal energy

The term geothermal energy should be stated in acts dealing with geothermal energy. The EU directive 2009/28/EC gives the following definition:

"Geothermal energy means the energy stored in the form of heat beneath the surface of the solid Earth".

In the sense of the definition, this includes geothermal energy exploited by any type of geothermal energy system, independent of method, depth or temperature level. Since there are some crucial differences between the exploitation of shallow and deep geothermal energy, in particular regarding scope and drilling techniques, it is necessary to define a criterion for procedural distinction between these two types.



modified after Umweltministerium Baden-Württemberg, 2005. Specified values and uses are to be understood as directional signs.

Figure 3: Exploitation of geothermal energy

A depth limit for the distinction between shallow and deep geothermal energy is commonly used. This varies between countries (in GeoPLASMA-CE countries from 100 to 400 m, more information available in deliverable D.T2.4.2 *Catalogue of reviewed quality standards, current policies and regulations*) and is derived from technical standards and other non-binding guidelines. The determination of the depth limit follows a number of reasons, e.g. drilling depths set in mining laws. A suitable definition may also use underground temperature or energy extraction in combination with a depth limit as defining criterion. From a technical and scientific point of view, any such distinction criterion between shallow and deep geothermal energy is an arbitrary value. However, from an economic, legal and social point of view a distinction is necessary.

In the sense of harmonization, cross-border management plans, legal certainty, conflict avoidance and analysis of statistics, a common definition of shallow geothermal energy is required.

A definition by depth seems to be a logical conclusion, since this is the most common in currently existing definitions.

4.1.2. Installation size

A distinction between large scale and small-scale installations is advisable for the handling of SGES. The occurrence of environmental risks and conflicts does not depend on installation size; the extent of influences, however, does. Consequently, some quality standards require different specifications for small and large-scale installations. A common definition of installation sizes based on the peak capacity is advisable due to its simplicity.

Table 3: GeoPLASMA-CE SGES-classes according to their installation size respectively, power. This table also gives recommendations related to quality standards. Explanations are given in the individual chapters of this document. Source: GeoPLASMA-CE workshop, 2018.

Class	S	M	L
Power [kW]	<12	12-50	>50
Example	Single Family House	Multi Family House	Commercial Building
Licencing - user	Facilitated submission for user		
Energy	heat /(cool)	heat /cool	h/c/storage
Thermal Response Test	No	Recommended	Obligatory
Thermal spread	Calculated	Numerical modelling	
Monitoring (system efficiency)	Voluntary		
Monitoring (environmental impact)	Basic	Advanced	Full

In addition, a distinction between installations sizes would also allow harmonized alleviation of legal and financial obligations, e.g. regarding monitoring or other stipulations of the license, for small usages. In some countries, the categorization by installation capacity has already been implemented in order to accommodate simplified application procedures or notification schemes for small-scale installations. Table 3 shows a suggestion for the division of SGE installations in three categories by installed capacity, and presents different aspects of SGE management, which could depend on installation size.

The distinction between installations according to their size should be defined by selecting appropriate capacity criteria.

4.1.3. Ownership

With an increasing density of shallow geothermal installations and insufficient information about existing installations, the risk of mutual influence and reduced efficiency of installations is increasing. Currently, there are no clear recommendations for the resolution of conflicts arising from such mutual influence.

The ownership of geothermal energy itself is not regulated in any of the GeoPLASMA-CE partner countries. Ownership of geothermal energy is closely related to ownership of the underground and of the groundwater. These may belong to the state, the municipality, the public or the property owner.

In fact, not the ownership of geothermal energy is crucial but the awarding of exploitation rights. Access to geothermal energy is often dealt by a “first come, first serve” approach. The license may contain stipulations that preclude or limit thermal impact on neighboring properties.

In GeoPLASMA-CE partner countries, unlike other underground resources such as minerals and groundwater, geothermal exploitation rights are not covered by comprehensive management plans of the subsurface.

The ownership of geothermal energy and access rights to geothermal energy should be clarified and subject to a spatially comprehensive management document. This should be anchored in the legal system of the countries. GeoPLASMA-CE suggests allocating geothermal energy quotas to properties or surface areas even in countries with state ownership. This method favours the sense of integrative management and supports an efficient use of geothermal energy overcoming the “first come - first serve” principle.

4.2. Certifications and Training

GeoPLASMA-CE surveys identified certification as the most powerful tool to ensure a high standard of quality for the implementation of shallow geothermal energy systems. The renewable energy directive also demands certification schemes for geothermal systems. Although differences are not great, survey results indicate that certification for drilling personnel is deemed more important than certification for planners / designers and that the need for certification appears to become greater with installation size. In addition, a stakeholder survey indicated a need to train the local authorities to ensure consistent decision-making.

The introduction of a basic certificate that covers the whole range of working steps during the implementation of geothermal energy systems is highly recommended for:

- Design
- Drilling and construction
- Installation
- Maintenance
- Licensing authorities

The certificate should be only available for personnel with technical background. This ensures that the whole process of implementation is on the same required minimum level of expertise. Extra training for single working steps is highly favourable.

Various certificates already exist, even if in different ways. A pan-European certificate guarantees harmonization and thus simplification. It also supports entry of foreign companies into the market even if national certification is absent. GeoTRAINET for example provides training for drillers and planners but not installers.

A mandatory certification for drillers, installers, planners, maintenance contractors and auditing authorities is recommended. Organisations like GeoTRAINET can be an example and provide further details. It is also recommended to verify and enforce compliance of involved parties. Penalties can also be an instrument to ensure qualified personnel, as is the employment of certified personnel as a requirement for funding.

4.3. Technical quality standards

Previous analyses performed in this project show that the state of the art varies between the countries involved in GeoPLASMA-CE with respect to technical and ecological standards. For this deliverable, the GeoPLASMA-team aims at elaborating common minimum quality standards. Quality standards can be technical standards for installation and operation but also standards for the compliance with quality control measures (e.g. drilling reports and system monitoring). A detailed definition of these standards is beyond the focus and expertise of GeoPLASMA-CE. Existing standards, guidelines and norms are listed in (ANNEX 2).

Compliance with quality standards during all stages of the Management Loop is indispensable to ensure an efficient, environmentally safe, sustainable and renewable operation.

Quality standards should refer to the state of the art expressed in guidelines, rulebooks or (legal) norms.

It is strongly recommended to consider all standards in the management loop of shallow geothermal energy use.

ANNEX 3 – "GeoPLASMA-CE – Technical quality standards: A guide for planning and licencing" – helps to determine the minimum requirements for technical quality standards.

4.4. Local geographical and geological conditions

Shallow geothermal energy is available anywhere and SGE installations can be realized almost anywhere. In order to design an efficient and sustainable SGE installation, local information are required:

1. **Expected yield**

Some areas might give higher thermal yields than others might due to local aquifer properties or rock properties, respectively. The absence of reliable data enhances the use of literature values, estimates and other approximations and may give unsatisfactory results.

2. **Legally regulated areas**

There may be restrictions placed on certain areas, e.g. water protection zones, where drilling is subject to specific conditions. Legally binding areas are stated in documents like decrees or edicts, which are publicly available.

3. **Drilling hazards**

Certain geological or hydrogeological conditions may call for additional technical or safety measures, e.g. in the presence of artesian aquifers or anhydrite. ANNEX 4 shows examples for adverse conditions that should be taken into account during the planning stage. Presence of any of these examples does not by any means imply that SGE cannot be realized in such areas. Rather than that, the potential impact should be considered during the planning phase and appropriate precautionary measures should be taken. Suggestions for such measures are also presented in ANNEX 4. The table is not comprehensive and only reflects issues encountered by GeoPLASMA-CE partner countries.

Information relating to local geographical and geological conditions are not available everywhere. Where they are available, standards differ widely between countries and regions: The physical quantities and symbology of potential maps are different, as are categorization and presentation of hazards and land-use conflicts. For this reason, GeoPLASMA-CE produced standardized and harmonized workflows for the creation of potential maps, land-use conflict maps and suitability maps. These workflows are available in deliverable D.T2.3.4 *Evaluated guidelines on harmonized workflows and methods for urban and non-urban areas*. This deliverable also includes suggestions for a harmonized data management and symbology).

Relevant geological and hydrogeological conditions and risk factors should be determined for each region. Risk maps should be created accordingly and provided for SGE planning and licensing.

A definition for aquifers suitable for open-loop systems should be elaborated. This definition could be based on criteria such as aquifer thickness, yield, hydraulic conductivity or a combination thereof.

GeoPLASMA-CE recommends providing the following maps as a minimum requirement:

For closed-loop systems

- Average thermal conductivity in suitable depth intervals
- Geological information
- Mining and other subsurface cavities
- Artesian and confined aquifers
- Relevant geological and hydrogeological risk factors
- Water protection zones
- Contaminated areas
- Suitability map for closed-loop systems (“traffic light map”)
- Existing geothermal installations (if consistent with existing national data protection regulations)

For open-loop systems

- Outline of suitable aquifers
- Hydraulic productivity
- Artesian and confined aquifers
- Groundwater chemistry
- Contaminated areas
- Water protection zones
- Suitability map for open-loop systems (“traffic light map”)
- Existing geothermal installations (if consistent with existing national data protection regulations)

5. ANNEX

ANNEX 1	Self-Assessment sheets
ANNEX 2	List of standards
ANNEX 3	Technical quality standards: A guide for planning and licencing.
ANNEX 4	Drilling hazards recommendation table
ANNEX 5	Parameter explanations for the monitoring chapter

CATALOGUE OF SUCCESS CRITERIA FOR A SUSTAINABLE MANAGEMENT OF SHALLOW GEOTHERMAL USE

ANNEX 1

ASSESSMENT SHEETS FOR THE MANAGEMENT OF SHALLOW GEOTHERMAL USE

Deliverable: D.T2.5.1

Project partner: LP-GBA

03/2019

Assessment sheet: Prerequisites for an integrative management of shallow geothermal energy

Management of shallow geothermal energy systems		YES	NO
	Are integrative management methods used?		
	Are the targets of geothermal energy management clearly defined?		
	Does information from existing installations feed back into the planning and licensing of new installations?		

Legal framework		YES	NO
	Does the legal framework accommodate shallow geothermal energy?		
	Is there a clear definition of the term "shallow geothermal energy"?		
	Are access rights/exploitation rights to geothermal energy clearly regulated?		
	Is ownership of geothermal energy clearly regulated?		

Quality standards		YES	NO
	Do existing technical standards include SGE?		
	Do legal regulations specify the documents representing the state of the art?		
	Are SGE installations categorized by installed capacity?		
	Are the technical aspects clearly defined and regulated?		
	Is there a definition for "negative impact" on neighboring SGE installations or on other usages?		
	Are pumping tests mandatory for open loop systems?		
	Is reinjection into the same groundwater body the stated preferred method for open loop systems?		
	Are there any temperature limitations for reinjected groundwater specified?		
	Is the installation of pilot installations required for large scale installations?		
	Is in-situ thermal response testing obligatory for closed-loop systems?		
	Are binding quality checks defined for the installation (e.g. leakage tests?)		

Certification		YES	NO
	Is shallow geothermal energy design a certified or protected profession?		
	Are specific certificates for drillers and/or installers existing, which exceed standard professional licenses for drillers, well constructors or installers?		
	Does authority staff need specific certificates for the evaluation of applications for shallow geothermal systems?		

Planning / Design		YES	NO
	Are technical state of the art standards provided by regulators in terms of legal acts, guidelines or handbooks?		
	Do authorities provide consulting during the planning phase?		
	Are routines and calculation schemes for system designs (e.g. dimensioning of BHEs) provided by public bodies?		
	Do regulators provide basic spatial information on sensitive geological zones or drilling hazards?		
	Do regulators provide basic spatial information on limitation of use of shalllow goethermal energy (e.g. water protection zones)?		
	Are basic maps and data describing the (hydro-) geological subsurface conditions provided by the public bodies?		
	Is it mandatory to use the data provided by the information system for the design of an shallow geothermal energy installation?		

Licensing		YES	NO
	Does the use of shallow geothermal energy require always a permit?		
	Has a one-stop-shop scheme been implemented, so the applicant does not have to approach more than one authority during the licensing procedure?		
	Does the authority provide online support such as application forms, explanatory notes and guidelines on the application process?		
	Are contact details for the responsible authorities easily accessible from websites and printed guidelines?		
	Does the licensing authority provide a full electronic submission and communication system for applications?		
	Is there a maximum time limit specified for the duration of the licensing process?		
	Are the operational licenses (permits) granted for a specified period of time? (expiration date)		
	Is there an procedure in place which is triggered automatically by license expiration? E.g. notification of owner, re-evaluation, verification of abandonment etc.		
	Are licensed installations collected in registers (a cadastre)?		

NOTES:

Assessment sheet: Success criteria for the installation and operation of shallow geothermal energy systems

Local geographical and geological conditions	YES	NO
Are the relevant geological and hydrogeological risk factors identified?		
Are risk maps available?		
Are confilict maps available?		
Is there a definition for "suitable aquifer" with regards to open loop systems?		
Are the most essential maps as listed by GeoPLASMA-CE (D.T2.5.1 chapter 4.4) available?		

Installation	YES	NO
Is it mandatory to document the drilling, installation and commissioning of an shallow geothermal energy system?		
Is it obligatory to report the accomplishment of the installation to the authority?		
Is the authority empowered to perform in-situ quality checks during or after the installation?		
Does the documentation of installation results include in-situ measurements on record by the licensing authority and are these data publicly accessible?		

Operation	YES	NO
Are operational criteria provided by the regulators in terms of legal acts, guidelines or handbooks?		
Are technical standards existing how to use shallow geothermal systems in an efficient way?		
Is it mandatory to abandon a shallow geothermal energy installation after the end of the operational time?		
Are regular service intervals and maintenance tasks defined in guidelines?		
Is it mandatory to report leakage of heat-carrier fluid to the authorities?		
Are the obligation to report leakage of heat-carrier fluid as well as the local contact details included in the permit or easily accessible online?		
Is compliance with legal regulations and stipulations specified in the permit verified and enforced by the authorities?		
Is compliance with legal regulations and stipulations fostered?		

Abandonment	YES	NO
Are abandonment and reasons for abandonment defined in legally binding documents?		
Do the authorities have to be notified of decommissioning or abandonment?		
Are there binding technical guidelines which detail the abandonment procedure?		
Is the decommissioning or abandonment notification used to update the information system and adjust the environmental monitoring schedule?		

NOTES:

Assessment sheet: Success criteria for the monitoring of shallow geothermal energy systems

Monitoring		YES	NO
	Are technical standards related to monitoring (parameters, devices, intervals, installation) defined in guidelines or handbooks?		
	Are any specific environmental monitoring programs operated by public bodies with a focus on shallow geothermal energy?		
	Do guidelines recommend system efficiency monitoring to all shallow geothermal energy operators?		
	Are there detailed guidelines which advise the licensing authorities in which circumstances they have to mandate monitoring, and which parameters, intervals and time periods should be proscribed?		
	Are there detailed guidelines which advise the licensing authorities in which circumstances existing licenses can be extended, and in which circumstances extensions should be denied?		
	Does the scope of monitoring activities depend on installation type?		
	Does the scope of monitoring activities depend on installation size (capacity)?		
	Is an initial groundwater analysis mandatory for all open loop installations?		
	Is the recording and reporting of annual volume pumped, temperature in and temperature out mandatory for all open loop installations?		
	Are the scope and schedule of environmental monitoring activities by authorities specified?		
	Is environmental monitoring performed for as long as the installation is operational?		
	Is there a binding definition for the term "suitable observation well"?		
	Are there any guidelines detailing the collection and interpretation of environmental impact monitoring data?		
	Is collection and interpretation of environmental impact monitoring data performed by the authorities or independent third parties?		
	Is the authority or independent third party informed about the expiration dates of individual licenses?		

NOTES:

Assessment sheet: Success criteria concerning information systems for shallow geothermal energy use

Information Systems		YES	NO
	Is a web-based information system available?		
	Does the information system allow location-specific queries?		
	Is the information system linked to an online application system?		
	Is data content verified to be factually correct?		
	Are intervals for revision specified for each data set?		
	Is the information system linked to other public information systems?		
	Is data access free of charge?		
	Is data access intuitive and user friendly?		
	Does the information system contain installation-specific data such as location, depth and capacity?		
	Are monitoring data used to update web based information systems or publicly accessible datasets?		
	Has an appropriate method for collecting privately owned monitoring data been established?		
	Is the user interface updated regularly to reflect current practices and software versions (e.g. browser compatibility)?		
	Is the information system protected against unauthorized access and data manipulation?		
	Are different access levels implemented?		
	Is access in compliance with national and EU regulations regarding data protection?		
	Is access to privately owned data restricted to persons with a demonstrable vested interest?		
	Does the information system provide hydrogeological information such as hydraulic connectivity, aquifer thickness or hydrochemistry?		
	Does the information system provide geological information?		
	Does the information system provide geothermal information, such as thermal conductivities, geothermal gradient, subsurface temperatures or heat extraction rates?		
	Does the information system provide information on land-use conflicts such as water protection areas or cavities (i.e. underground mining, tunnels and natural caves)?		
	Does the information system provide information on geological or drilling hazards such as presence of anhydrite, karst, swelling clays, contaminated land or artesian aquifers?		
	Does the information system provide suitability maps for open-loop and closed-loop systems?		
	Does the information system provide time or depth series of data from observation wells, such as groundwater levels, groundwater temperature profiles or groundwater analyses?		

NOTES:

CATALOGUE OF SUCCESS CRITERIA FOR A SUSTAINABLE MANAGEMENT OF SHALLOW GEOTHERMAL USE

ANNEX 2
LIST OF CURRENT STANDARDS

Deliverable: D.T2.5.1

Project partner: LP-GBA

03/2019

EUROPEAN STANDARDS modified after ReGeoCities (D3.4, 2015)

Heat Pumps

EN 378 - 1:2008+A2:2012 Refrigerating systems and heat pumps. Safety and environmental requirements. Basic requirements, definitions, classification and selection criteria

BS EN 378 - 2:2008+A2:2012 Refrigerating systems and heat pumps. Safety and environmental requirements. Design, construction, testing, marking and documentation

EN 378 - 3:2008+A1:2012 Refrigerating systems and heat pumps. Safety and environmental requirements. Installation site and personal protection

BS EN 378 - 4:2008+A1:2012 Refrigerating systems and heat pumps. Safety and environmental requirements. Operation, maintenance, repair and recovery

EN 14511 - 1:2013 Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling. Terms, definitions and classification

EN 14825:2013 Air conditioners, liquid chilling packages and heat pumps, with electrically driven compressors, for space heating and cooling. Testing and rating at part load conditions and calculation of seasonal performance

EN 12171:2002 Heating systems in buildings. Procedure for the preparation of documents for operation, maintenance and use. Heating systems not requiring a trained operator

Materials

EN 12201 - 1:2011 Plastics piping systems for water supply, and for drainage and sewerage under pressure. Polyethylene (PE). General

ISO 4427 - 1:2007 Plastics piping systems -- Polyethylene (PE) pipes and fittings for water supply -- Part 1: General

ISO 4427 - 2:2007 Plastics piping systems --Polyethylene (PE) pipes and fittings for water supply -- Part 2: Pipes

ISO 4427 - 3:2007 Plastics piping systems -- Polyethylene (PE) pipes and fittings for water supply
- Part 3: Fittings

ISO 4427 - 5:2007 Plastics piping systems -- Polyethylene (PE) pipes and fittings for water supply
- Part 5: Fitness for purpose of the system

Design

EN 12828: 2012 + A1:2014: BS EN 12828: 2012 + A1: 2014. Heating systems in buildings. Design for water-based heating systems

EN 12828: 2003: BS EN 12828:2003. Heating systems in buildings. Design for water-based heating systems

EN 15316 -1: 2007: BS EN 15316 - 1:2007. Heating systems in buildings. Method for calculation of system energy requirements and system efficiencies. General

EN 15316-2-1: 2007: BS EN 15316 -2-1:2007. Heating systems in buildings. Method for calculation of system energy requirements and system efficiencies. Space heating emission systems

EN 15316-2-3: 2007: BS EN 15316-2-3:2007. Heating systems in buildings. Method for calculation of system energy requirements and system efficiencies. Space heating distribution systems

EN 15316-3-1: 2007: BS EN 15316-3-1:2007. Heating systems in buildings. Method for calculation of system energy requirements and system efficiencies. Domestic hot water systems, characterisation of needs (tapping requirements)

EN 15316-3-2: 2007: BS EN 15316-3-2:2007. Heating systems in buildings. Method for calculation of system energy requirements and system efficiencies. Domestic hot water systems, distribution

EN 15316-3-3: 2007: BS EN 15316-3-3:2007. Heating systems in buildings. Method for calculation of system energy requirements and system efficiencies. Domestic hot water systems, generation

EN 15316-4-2:2008: BS EN 15316-4-2:2008. Heating systems in buildings. Method for calculation of system energy requirements and system efficiencies. Space heating generation systems, heat pump systems

EN 15450: 2007: BS EN 15450:2007. Heating systems in buildings. Design of heat pump heating systems

ISO 7519: 1991 Technical drawings --Construction drawings --General principles of presentation for general arrangement and assembly drawings

Installation and Commissioning

EN 14336: 2004: BS EN 14336:2004. Heating systems in buildings. Installation and commissioning of water based heating systems

ISO 22475-1: 2006 Geotechnical investigation and testing --Sampling methods and groundwater measurements --Part 1: Technical principles for execution

ISO 21307: 2011 Plastics pipes and fittings --Butt fusion jointing procedures for polyethylene (PE) pipes and fittings used in the construction of gas and water distribution systems

EN 805: 2000: BS EN 805:2000. Water supply. Requirements for systems and components outside buildings

Maintenance & Testing

ISO 14686: 2003 Hydrometric determinations --Pumping tests for waterwells --Considerations and guidelines for design, performance and use

ISO 13256 -1:1998 ISO 13256-1:1998. Water-source heat pumps. Testing and rating for performance. Part 1: Water-to-air and brine-to-air heat pumps

ISO 13256-2:1998 ISO 13256-2:1998. Water-source heat pumps. Testing and rating for performance. Part 2: Water-to-water and brine-to-water heat pumps

GUIDELINE DOCUMENTS OF DIFFERENT LEGAL STATUS ADRESSING THE IMPLEMENTATION OF SHALLOW GEOTHERMAL ENERGY modified and complemented after Sanner (at EnerSTOCK 2018)

Table 1: Guidelines issued by the individual Federal States of Germany. Modified after Sanner, 2017.

State	Title (German original title)	Topic(s) covered	Year of latest edition
Baden-Württemberg	Leitfaden zur Nutzung von Erdwärme mit Erdwärmesonden[1]	BHE (vertical loops)	2005
	Leitfaden zur Nutzung von Erdwärme mit Erdwärmekollektoren	Horizontal loops	2008
	Leitfaden zur Nutzung von Erdwärme mit Grundwasserwärmepumpen	Ground-water wells	2009
Bayern (Bavaria)	Leitfaden Erdwärmesonden in Bayern[2]	BHE	2012
Berlin	Erdwärmenutzung in Berlin, Merkblatt für Erdwärmesonden und Erdwärmekollektoren…	BHE and horizontal loops	2017
Brandenburg	Nutzung von Erdwärme in Brandenburg	BHE, horiz. loops, wells	2009
Hamburg	Leitfaden zur Erdwärmenutzung in Hamburg	BHE and horiz. loops	2016
Hessen	Erdwärmenutzung in Hessen, Leitfaden für Erdwärmesondenanlagen zum Heizen und Kühlen	BHE	2017
Mecklenburg-Vorpommern	Erdwärmesonden und Erdwärmekollektoren in Mecklenburg-Vorpommern	BHE and horiz. loops	2015
Niedersachsen (Lower Saxony)	Leitfaden Erdwärmenutzung in Niedersachsen, rechtliche und technische Grundlagen[3]	BHE, horiz. loops, wells	2012
Nordrhein-Westfalen	Merkbl. 48, Wasserwirtschaftliche Anforderungen an die Nutzung von oberflächennaher Erdwärme	BHE, horiz. loops, wells	2004

Rheinland-Pfalz (Rhineland-Palatinate)	Leitfaden zur Nutzung von oberflächennaher Geothermie mit Erdwärmesonden	BHE	2012
Saarland	Leitfaden Erdwärmenutzung	BHE and horiz. loops	2008
Sachsen (Saxony)	Erdwärmesonden, Informationsbroschüre zur Nutzung oberflächennaher Geothermie	BHE	2014
	Grundwasserwärmepumpen, Merkblatt zum Bau und Betrieb	wells	2015
Sachsen-Anhalt	Erdwärmenutzung in Sachsen-Anhalt[4]	BHE	2012
Schleswig-Holstein	Leitfaden zur geothermischen Nutzung des oberflächennahen Untergrundes	BHE and horiz. loops	2011
Thüringen (Thuringia)	Nutzung oberflächennaher Geothermie, Arbeitshilfe zur wasserrechtlichen Beurteilung	BHE, horiz. loops, wells	2013

1 since 2010 a series of documents on quality control of BHE have been added (LQS EWS), latest issue in 2018

2 in addition a detailed document on planning and installation of BHE, Merkblatt Nr. 3.7/2 (2012)

3 draft version with intended revisions published in 2017

4 new edition under preparation; in addition a general brochure *"Geothermie in Nordrhein-Westfalen erkunden · bewerten · nutzen"* on all geothermal technologies from 2011 exists

5 in addition a document on quality control of BHE from 2016

Table 2: Guidelines issued by the individual Federal States of Austria. Source: Sanner, 2017.

State	Title (German original title)	Topic(s) covered	Year of latest edition
Burgenland	Wärmepumpen[1]	GSHP general	2016
Kärnten (Carinthia)	Merkblatt Grundwasserwärmepumpe	GW wells	2014
Niederösterreich (Lower Austria)	Wärmepumpen und Grundwasserschutz, Planung, Bau und Betrieb	BHE, horiz. loops, wells	2012
Oberösterreich (Upper Austria)	Merkblatt Erdwärmesonden (Tiefsonden)	BHE	2011
	Merkblatt Flachkollektor	Horiz. loops	2006
	Merkblatt Grundwasser-Wärmepumpen[2] bis 5 l/s	GW-wells	2006
Salzburg	Leitfaden Erdwärmesonden (Tiefsonden)	BHE	2017
Steiermark (Styria)	Die Gewinnung von Erdwärme in Form von Vertikalkollektoren (Tiefensonden) - Strategiepapier	BHE	2011
Tirol (Tyrol)	Leitfaden zum Bau und Betrieb von Erdwärmesonden in Tirol	BHE	2016
Vorarlberg	Nimm 4, zahl 1! Richtig heizen mit Erdwärme	GSHP general	2014
Wien (Vienna)	Erdwärme voraus! Die Erde als Energiequelle	BHE, horiz. loops, wells	2016

[1] in addition a document with a map for BHE

[2] Complemented by 4 documents on well placement etc.

Table 3: Standards explicitly addressing shallow geothermal technology. Modified after Sanner, 2017.

Name/Number	Original title	English title	Year
Europe – CEN[1]			
EN 15450	Heating systems in buildings – Design of heat pump heating systems	Heating systems in buildings – Design of heat pump heating systems	2007
EN ISO 17628	Geotechnical investigation and testing – Geothermal testing – Determination of thermal conductivity of soil and rock using a borehole heat exchanger	Geotechnical investigation and testing – Geothermal testing – Determination of thermal conductivity of soil and rock using a borehole heat exchanger	2015
Austria			
ÖWAV RB 207	Thermische Nutzung des Grundwassers und des Untergrundes – Heizen und Kühlen	Thermal use of groundwater and underground – Heating and cooling	2009
France			
NF X10-960-1	Forage d'eau et de géothermie – Sonde géothermique verticale – Généralités	Boreholes for water and geothermal – Vertical borehole heat exchangers – General issues	2013
NF X10-960-2	(Forage… verticale) – Boucle de sonde en polyéthylène 100 (PE 100)	(Boreholes… exchangers) – Pipe loops of polyethylene 100 (PE 100)	2013
NF X10-960-3	Forage… verticale) – Boucle de sonde en polyéthylène réticulé (PE-X)	(Boreholes… exchangers) – Pipe loops of cross-linked polyethylene (PE X)	2013
NF X10-960-4	Forage… verticale) – Boucle de sonde en polyéthylène de meilleure résistance à la température	(Boreholes… exchangers) – Pipe loops of polyethylene with higher temperature resistance (PE–RT)	2013
NF X10-970	(Forage… verticale) – Réalisation, mise en oeuvre, entretien, abandon d'ouvrages de captage ou de surveillance des eaux souterraines réalisés par forages	(Boreholes… exchangers) – Installations, commissioning, maintenance, abandonment	2011
NF X10-999	Forage d'eau et de géothermie – Réalisation, suivi et abandon	Boreholes for water and geothermal – Operation, supervision and abandonment	2014

		of groundwater wells for extraction or monitoring	
Name/Number	Original title	English title	Year
		Germany	
DIN 8901	Kälteanlagen und Wärmepumpen – Schutz von Erdreich, Grund- u. Oberflächenwasser	Refrigerating systems and heat pumps – Protection of soil, ground and surface water	20002
DVGW W 120-2	Qualifikationsanforderungen für die Bereiche Bohrtechnik und oberflächennahe Geothermie (Erdwärmesonden)	Qualification requirements for the sector of drilling technology and shallow geothermal (borehole heat exchangers)	2010
VDI 4640-1	Thermische Nutzung des Untergrunds – Grundlagen, Genehmigungen, Umweltaspekte	Thermal use fo the underground – Fundamentals, approvals, environmental aspects	2001
VDI 4640-2 [2]	(Thermische… Untergrunds) – Erdgekoppelte Wärmepumpen	(Thermal… underground) – Ground source heat pump systems	2001
VDI 4640-3	(Thermische… Untergrunds) – Unterirdische Thermische Energiespeicherung	(Thermal… underground) – Underground thermal energy storage	2001
VDI 4640-4	(Thermische… Untergrunds) – Direkte Nutzungen	(Thermal… underground) – Direct uses	2004
VDI 4640-5 [3]	(Thermische… Untergrunds) – Thermal response test	(Thermal… underground) – Thermal response test	2016
		Italy	
UNI 11466	Sistemi geotermici a pompa di calore – Requisiti per il dimensionamento e la progettazione	Geothermal systems with heat pump – requirements for the dimensioning and design	2012
UNI 11467	Sistemi geotermici a pompa di calore – Requisiti per l'installazione	Geothermal systems with heat pump – requirements for installation	2012
UNI 11468	Sistemi geotermici a pompa di calore – Requisiti ambientali	Geothermal systems with heat pump – evironmental requirements	2012
UNI/TS 11487	Sistemi geotermici a pompa di calore – Requisiti per l'installazione di impianti ad espansione diretta	Geothermal systems with heat pumpe – requirements for the installation of direct expansion systems	2013

Name/Number	Original title	English title	Year
UNI 11517	Sistemi geotermici a pompa di calore – Requisiti per la qualificazione delle imprese che realizzano scabiatori geotermici	Geothermal systems with heat pump – requirements for the qualification of companies installing geothermal heat exchangers	2013
		Spain	
UNE 100715-1	Diseño, ejeción y seguimiento de una instalación geotermica somera, parte 1: Sistemas de circuito cerrade vertical	Design, installation and maintenance of shallow geothermal installations – closed-loop vertical systems	2014
		Sweden	
SGU Normbrunn-16	Vägledning für att borra brunn	Guideline for drilling of wells	2016
		Switzerland	
SN 546 384/6 [4]	Erdwärmesonden	Borehole heat exchangers	2010
SN 546 384/7	Grundwasserwärmenutzung	Use of the heat of the groundwater	2015
		United Kingdom	
DECC MIS 3005 (version 5.0) [5]	Requirements for contractors undertaking the supply, design, installation, set to work commissioning and handover of microgeneration heat pump systems	Requirements for contractors undertaking the supply, design, installation, set to work commissioning and handover of microgeneration heat pump systems	2017
GSHPA (version 2) [6]	Good practice guide for ground source heating and cooling	Good practice guide for ground source heating and cooling	2017
GSHPA (version 2) [6]	Vertical Borehole Standard	Vertical Borehole Standard	2017
GSHPA (version 2) [6]	Shallow Ground Source Standard	Shallow Ground Source Standard	2018
GSHPA [6]	Thermal Pile – Design, Installation & Materials Standards	Thermal Pile – Design, Installation & Materials Standards	2012

1 CEN standards are adopted by the member organizations and issued, usually translated into national language, with adding the own national acronym
2 Draft of new, completely revised version published 2015
3 Published draft only
4 Sometimes also referred to as SN 565384-6
5 In addition MCS 022: Ground heat exchanger look-up tables (2011)
6 No numbers

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CATALOGUE OF SUCCESS CRITERIA FOR A SUSTAINABLE MANAGEMENT OF SHALLOW GEOTHERMAL USE

ANNEX 3

TECHNICAL QUALITY STANDARDS:

A GUIDE FOR PLANNING AND LICENCING

Deliverable: D.T2.5.1

Project partner: LP-GBA

03/2019

Geologische Bundesanstalt
LANDESAMT FÜR UMWELT, LANDWIRTSCHAFT UND GEOLOGIE
Freistaat SACHSEN
CZECH GEOLOGICAL SURVEY
GeoZS Geološki zavod Slovenije
AGH University of Science and Technology
geoENERGIE Konzept
GiGa infosystems
Bundesverband Geothermie
City of Ljubljana

INTRODUCTION

With "ANNEX3 – Technical quality standards – A guide for planning and licencing" the GeoPLASMA-CE team elaborated a document providing a base for uniform minimum technical standards for the implementation of shallow geothermal energy systems in Europe. In the sense of harmonization, a minimum base for technical quality standards is needed.

Presented parameters are already required in several countries in Central Europe, but lack a uniform handling. While some countries regulate some parameters very precisely others have no regulation. ANNEX 2 of "D.T2.5.1 –Success criteria for a sustainable management of shallow geothermal use" presents an overview of existing documents concerning quality standards and parameters in Europe.

This document is split into two parts:

Content:

Each part presents the minimum quality standards for the respective SGES and includes a detailed checklist for an easy control of their application. Quality standards display topics that have to be considered during planning/designing and that have to be checked during licencing procedures. The compliance of these quality standards is defined through specific technical parameters. According parameters are described in the second part of each main chapter.

A. Quality standards concerning closed loop systems (CLS)

1. Checklist for quality standards that have to be considered during planning/designing and licencing of CLS

CHECKLIST

Quality standards for closed loop systems

- [ ] Geological and hydrogeological report
- [ ] Knowledge of underground parameters
- [ ] TRT for large scale installations
- [ ] Groundwater analysis
- [ ] Consideration of neigbouring SGES
- [ ] Distance of single borhole heat exchangers
- [ ] Calculation of borhole length
- [ ] Numerical simulation for large scale installations
- [ ] Grouting of the borehole heat exchangers
- [ ] Leakage test of ground loop and refrigerant tubing
- [ ] Information of used materials
- [ ] Average temperatures of working fluids

2. Explanation of technical parameters to fullfill the compliance of quality standards for planning/design and licencing of CLS

2.1. Basis of design

a) Standards for the design of closed-loop systems

An appropriate design of a closed loop system ensures a sustainable use of the heat in the surrounding of the borehole heat exchanger. The design method must be adjusted to the size of the closed loop system.

It is recommended that material parameters used for CLS installation design are specified, either by providing the relevant values in guidelines or by mandating the use of a particular standard (e.g. latest release of VDI 4640-2, see ANNEX 2).

Small-scale to medium scale installations should be designed based on archive data, best experience and available guideline and the expected installed capacity (kW) of the systems.

Medium scale to large-scale installations should be designed based on TRT measurements (see section below) and numerical simulations (see section A.2.5).

b) Thermal Response Tests

Thermal response tests (TRT) help to explore underground-properties and therefore improve depth-calculations for closed loop systems and/or validate models. In addition, a TRT provides a significant optimization of cost that increases with the system size. For more information: GeoPLASMA-CE activity A.T3.5 focused on TRT.

TRT measurements are recommended for medium and large-scale installations.

Minimum shutdown period and minimum test duration should be specified in guidelines (see ANNEX 2 for existing documents).

2.2. Groundwater analysis

The groundwater composition can have adverse effects on CLS installations, e.g. at worst cement corrosion.

Groundwater analysis is recommended for all SGE installations where the groundwater composition is unknown. The sample can be taken from a nearby observation well, if available.

Limits for cement-corrosive groundwater components and appropriate remedial actions should be specified in technical guidelines to prevent connecting separate groundwater bodies.

It is recommended to create and publish data layers showing groundwater bodies with problematic groundwater chemistry. These data layers should be updated regularly (ideally every three years).

2.3. Minimum distances for closed loop systems

Minimum distances for the exploitation of geothermal energy with closed loop systems relate to the distance between individual borehole heat exchangers. Borehole heat exchangers influence their subsurface environment and thus potentially influence each other or neighbouring installations. The closer two heat exchangers are to each other, the higher is the risk of mutual temperature resource depletion causing lower overall system efficiency. This must be considered while planning/designing an installation.

Influences are to be excluded by specifying a suitable minimum distance (e.g. 10 % of BHE depth). For medium- and large-scale installations, a numerical simulation should be mandatory if mutual influence is expected.

2.4. Minimum distance to neighbouring installations

The mutual influence of SGES, which are placed too close to other installations, especially other SGES, reduces efficiency of both systems. Minimum distances to neighbouring installations avoid negative impacts concerning their performance. The determination is not useful since this follows a risk-based principle. A precautionary approach would be the consideration of neighbouring installations according to the environmental circumstances (aquifer and/or lithological properties) and the energy demand of both installation.

Thermal changes of the subsurface can affect the system efficiency of other installations, especially other OLS and CLS, if too close. We highly recommend the assessment of neighbouring installations during planning and the adaption of the minimum distance according to natural conditions and energy demand.

2.5. Numerical simulations

Numerical simulations help determining the interactions of the planned installation with the surrounding subsurface and with neighbouring geothermal energy systems. They also illustrate the mutual influence of a system's components (i.e. several BHE in an array).

Numerical simulations should be mandatory for medium and large-scale SGE installations.

A simplified analytical approximation of the propagation of thermal plumes in groundwater bodies should be performed prior to the numerical simulation. The approximated extent of the thermal plume will indicate whether mutual influence by existing installations can be expected, and it determines the necessary size of the modelling area. Existing installations must be considered if a mutual influence can be expected. The size of the modelling area should be sufficiently large to prevent boundary effects to the simulated plumes.

The numerical simulation should be based on a steady-state coupled thermal-hydraulic model covering the planned operation period of the installation.

Short-term peak loads do not have a significant impact on the surrounding subsurface on the long term. Therefore, in order to model the installation's impact correctly, the simulation should reflect the planned annual energy extraction / injection rather than the individual thermal loads (note: a high precision in both energy consumption and thermal load can only be achieved by applying short time steps during the simulation which is quite resource intensive).

Validation of the numerical model based on operational monitoring data should be mandatory for large-scale installations. The observation period should cover at least the first 3 years of operation and should include passive monitoring of observation wells located downstream of the monitored installation.

For medium-sized installations, abovementioned validation and adjustment of the numerical model based on monitoring data should be recommended.

For areas with a high density of installations, it is recommended that local authorities create and regularly update a numerical model at local to regional scale that considers existing installations based on a steady state approximation of the operational parameters (annual thermal work, annual yield) stated in the licenses. This model should be made publicly accessible and used for designing new installations and simulate their impact to avoid biased modelling assumptions.

Table 1: Summary of recommended methods for the design of CLS

	S	M	L
CLS	Empirical or analytical approximation based on master graphs (e.g. SIA guideline, ANNEX 2)	Numerical Simulation recommended if system size exceeds schemes for analytical approximations; Numerical simulation mandatory in case of expected significant influence of groundwater flow on the system	Numerical simulation mandatory

2.6. Negative impact to neighbouring installations

Negative impact to neighbouring installations is characterised by temperature changes. Temperature changes depend on the individual conditions and can be quantified by simulations in combination with long-term monitoring.

GeoPLASMA-CE recommends specifying the acceptable impact on the temperature conditions of neighbouring installations in legally binding documents.

2.7. Temperature of the heat carrier fluid

The temperature of the heat carrier fluid shall be selected to obtain a sustainable and yet efficient use. Excessively high heat extraction rates generate low soil temperatures, creating the risk of freezing, soil subsidence and low system efficiency. A range of norms, guidelines and standards defining temperature limits can be found in ANNEX 2.

Critical temperature values and operation limits for heat pumps for a) peak load and b) average throughout the heating period should be specified in technical guidelines or legally binding documents.

Expected temperature of the heat carrier fluid at the end of the installation's lifetime should be calculated. This temperature should exceed 4°C to prevent freeze-thaw cycles.

3. Explanation of standards important for the installation of the borhehole heat exchangers

3.1. Borehole drilling report and sampling

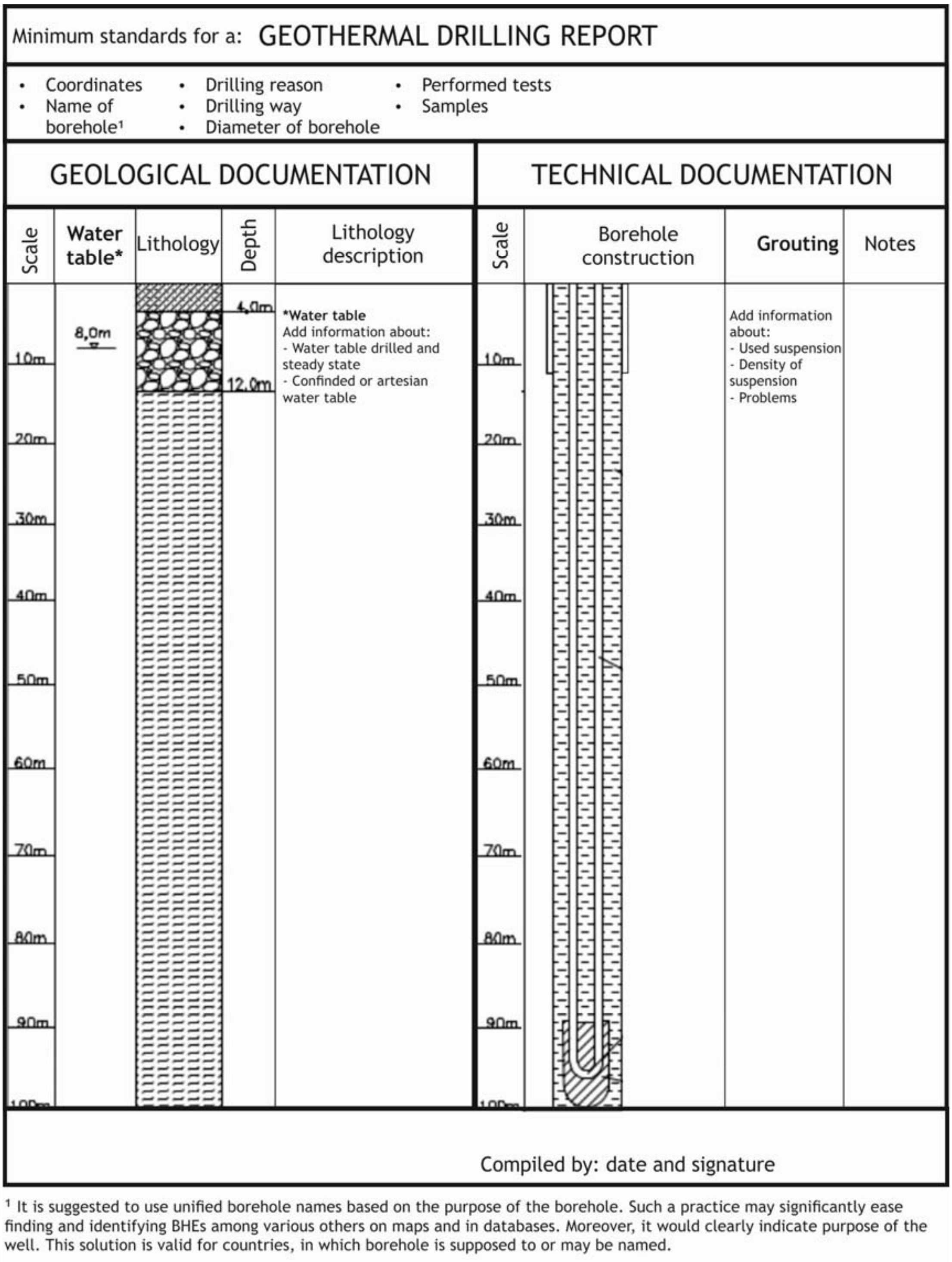

Figure 1: Example for a borehole drilling report

Lithological information, ground water levels, drilling method, borehole diameter, drilling fluid system and other information may be collected by authorities such as the geological survey, and is important for quality control (system design and efficiency) and environmental control. Cutting samples are also an instrument for quality control. They also serve as proof that the dimensioning based on thermal conductivities is appropriate. Therefore, they also help to determine the depth required for following wells. In some countries geological surveys or the local authorities may request cutting samples, e.g. in regions of complex geology or if drilling depth is limited for geologic reasons (e.g. presence of anhydrite, aquiclude). Figure 1 provides an example for a geothermal borehole drilling and installation report.

Completion of a geological report should be mandatory for all installations irrespective of installation type or size. The geological report should contain a lithological profile in compliance with national standards, drilled groundwater tables and the completion scheme. The contents of the drilling report and the handling of cuttings should be specified and should be suitable to serve as proof of proper execution and plausible installation design.

A suitable system for responses is to be implemented. It is recommended that authorities or geological services collected drilling reports for the assessment and inclusion in databases.

3.2. Regulations for the grouting of borehole heat exchangers

Grouting has to be designed with the purpose to preserve groundwater quality, natural hydraulic conditions, groundwater regime and circulation. Where applicable, special attention has to be payed to hydraulic separation of the aquifers with different water quality, groundwater regime and pressure levels. Resistant grouting material is required in the presence of cement corrosive waters. In case of a closed loop system, the grouting material also plays an important role regarding the heat transfer between the BHE and rock environment. The grouting also provides mechanical support and protection to the casing.

Existing standards regarding grouting are quite heterogeneous in Europe (to the extreme that it may not be required at all in hard rock formations in Scandinavia).

Cementation of the entire length of the BHE should be mandatory in all geological environments with significant groundwater occurrence. In addition, quality control measures should be implemented.

3.3. Leakage test of ground loop and refrigerant tubing

A leakage test highlights issues with the correct installation and functioning of equipment and can thus minimize adverse impact on the environment. As a quality control measure, it can prevent high follow-up costs and/or reduced efficiency of the system.

Leakage tests during the installation phase should be mandatory for all BHE systems. Leakage tests should be performed with a non-hazardous fluid (usually drinking water) and prior to filling the system with heat carrier fluid. The test pressure has to be higher than the operating pressure and has to be maintained for a suitable period. Test conditions have to be specified in binding guidelines (see ANNEX 2 for existing documents).

If the heat carrier fluid is a material hazardous to groundwater, appropriate control measures have to be implemented and appropriate training has to be provided to personnel (ANNEX 2).

Degassing checks of the heat carrier system are recommended.

Beside leakage test, also the pressure drop at fluid circulation is important to reveal the eventual narrowing or obstacles in the tubes. Inspections can be made visual just before installation, testing during completion and finally after completion.

B. Quality standards concerning open-loop systems (OLS)

1. Checklist for quality standards that have to be considered during planning/designing and licencing of OLS

CHECKLIST

Quality standards for open loop systems

- [ ] Geological and hydrogeological report
- [ ] Groundwater analysis
- [ ] Pumping test
- [ ] Consideration of neigbouring SGES
- [ ] Volume of extracted water
- [ ] Temperature difference between extracted and reinjected water
- [ ] Absolute temperatures range of the reinjected water
- [ ] Description of reinjection
- [ ] Calculation of the minimum distance between pumping and reinjection well
- [ ] Numerical simulation for large scale installations
- [ ] Temperature change and drawdownat neigbouring wells
- [ ] Information of used materials

2. Explanation of technical parameters to fullfill the compliance of quality standards for planning/design and licencing of OLS

2.1. Groundwater analysis

The groundwater composition can have adverse effects on SGE installations, e.g. scaling or metal corrosion. This is particularly important for open-loop systems where groundwater is part of the system and passes through the heat exchanger. Groundwater analysis helps choosing the correct equipment and preventing these impacts.

Groundwater analysis is recommended for all SGE installations where the groundwater composition is unknown. The sample can be taken from the well in question or from a nearby observation well, if available.

It is recommended to create and publish data layers showing groundwater bodies with problematic groundwater chemistry. These data layers should be updated regularly (ideally every three years).

2.2. Pumping test

A pumping test ensures that the design of the open loop system and the available groundwater body are matching. Pumping tests also allow to calculate the hydraulic conductivity values.

The required yield must be confirmed and it has to be proven that the produced water can be re-infiltrated into the aquifer without adverse impact. Pumping and reinjection tests should be mandatory for medium and large scale OLS installations, for small scale installations if there is no knowledge about the aquifer. Nevertheless, for medium and large-scale installation they are advisable to create validated hydraulic conductivities for numerical simulations.

Results of pumping tests should be collected by responsible authorities and should be publicly available. This helps to create knowledge about the aquifer and enhances future installations.

2.3. Temperature difference between extracted and reinjected water

The higher the temperature difference between extracted and reinjected groundwater at a given flow rate, the higher the energy production. However, higher temperature differences can cause larger changes to geochemical and ecosystem conditions and increase activity of bacteria and micro-fauna, which may decrease the groundwater quality.

A maximum permissible temperature difference between extracted and reinjected groundwater should be specified. The license should state the maximum thermal work per year for each installation for both heating and cooling. This limit should not be exceeded.

If a significant density of SGE installations is already present in a certain area (e.g. urban settlement), it is recommended to implement a comprehensive subterranean heat management and link maximum allowed temperature shift to groundwater temperature maps.

Temperature shift at peak load should remain within the specified range of absolute temperatures for reinjected water and should not be exceeded for a more than a specified number of hours per year.

2.4. Absolute allowable temperature range of the reinjected water

A temperature change of the groundwater influences the viscosity, oxygen saturation and the solution behaviour of the water. Temperature changes may also affect the micro fauna of the groundwater. Those environmental effects are greater with increasing temperature differences. Excess cooling also may affect the heat pump freezing.

It is recommended to specify absolute temperature limits for reinjected groundwater.

It is recommended that the minimum temperature is higher than 4°C and that the maximum temperature limits considers national requirements for drinking water.

In heavily used groundwater bodies, it is recommended to specify maximum allowable temperature levels based on assessment of microbiological conditions.

2.5. Reinjection of used groundwater

Reinjection of groundwater prevents depletion of the aquifer but bears the risk of contamination. Reinjection maintains groundwater levels and pressures. It therefore minimizes possible negative impacts on the extraction rates of nearby wells. However, temperature changes will be observed in the ground water. This could lower the efficiency of geothermal wells located downstream if not considered. However, given the right hydrogeological conditions, this could also allow using the aquifer as seasonal temperature storage (heating/cooling).

Thermally used water should be reinjected into the groundwater body. The legal framework should encourage reinjection, e.g. by eliminating water extraction fees.

Reinjection should take place in such a way that the groundwater table remains at an appropriate depth below surface.

Suitable control measures to ensure the hydraulic separation of heat carrier fluid and groundwater have to be in place.

Surface soakaways are cheaper to realize but require a large suitable surface area with appropriate subsurface conditions (permeability). Compared to reinjection wells, a soakaway does not directly reinject the used water to the aquifer. Soakaways thus provide more safety in case of pollution (principle of shallow reinjection), but also lead to aquifer depletion since not all of the produced water reaches the aquifer due to evapotranspiration.

It is recommended to specify reinjection into the same groundwater body as the preferred method. It is recommended to limit the application of soakaways to small-scale installations producing from the topmost aquifer. It is recommended to limit the application of soakaways to areas with sufficiently shallow groundwater table.

In case of low hydraulic conductivities or low overburden thickness above the groundwater table, horizontal injection wells should be erected.

2.6. Minimum distances for open loop systems

Reinjecting too close to or upstream of the extraction well will reduce the temperature of extracted water and thus lower system efficiency (hydraulic short circuit). Neighbouring SGES, no matter if OL or CL, may also be affected by temperature or changes of the groundwater level. The determination of fixed minimum distances is not advisable since distances must be adapted to the natural conditions of the aquifer.

For further recommendations, see section numerical simulations to prevent a hydraulic short-circuit.

Thermal changes of the subsurface can affect the system efficiency of other OLS and CLS if too close. We highly recommend to adapt the minimum distance according to natural conditions, energy demand and the assessment of neighbouring SGES during planning.

2.7. Minimum distance to neighbouring installations

The mutual influence of SGES, which are placed too close to other installations, especially other SGES, reduces efficiency of both systems. Minimum distances to neighbouring installations avoid negative impacts concerning their performance. The determination is not useful since this follows a risk-based principle. A precautionary approach would be the consideration of neighbouring installations according to the environmental circumstances (aquifer properties) and the energy demand of the planned installation.

Thermal changes of the subsurface can affect the system efficiency of other installations, especially other OLS and CLS, if too close. We highly recommend the assessment of neighbouring installations during planning and the adaption of the minimum distance according to natural conditions and energy demand.

2.8. Negative impact to neighbouring installations

Negative impact to neighbouring installations is characterised by temperature changes, drawdown and in minor cases by rise of groundwater. Temperature changes depend on the individual conditions and can be quantified by simulations in combination with long-term monitoring. Drawdown affects all types of wells in the vicinity and reduces their maximum extraction rates. Excessive drawdown can also result in chemical damage (scaling) of the well in question or can cause stability problems. Groundwater rise can lead to waterlogging and potential damages to building and installation in the vicinity.

GeoPLASMA-CE recommends specifying the acceptable impact on neighbouring installations in legally binding documents. The specifications can be based on groundwater temperature, drawdown/rise-up and reduction in installation output or a combination thereof.

2.9. Numerical simulations

Numerical simulations help determining the interactions of the planned installation with the surrounding subsurface and with neighbouring geothermal energy systems. They also illustrate the mutual influence of a system's components (i.e. several BHE in an array).

Numerical simulations should be mandatory for medium and large-scale SGE installations.

A simplified analytical approximation of the propagation of thermal plumes in groundwater bodies should be performed prior to the numerical simulation. The approximated extent of the thermal plume will indicate whether mutual influence by existing installations can be expected, and it determines the necessary size of the modelling area. Existing installations must be considered if a mutual influence can be expected. The size of the modelling area should be sufficiently large to prevent boundary effects to the simulated plumes.

The numerical simulation should be based on a steady-state coupled thermal-hydraulic model covering the planned operation period of the installation.

Short-term peak loads do not have a significant impact on the surrounding subsurface on the long term. Therefore, in order to model the installation's impact correctly, the simulation should reflect the planned annual energy extraction / injection rather than the individual thermal loads (note: a high precision in both energy consumption and thermal load can only be achieved by applying short time steps during the simulation which is quite resource intensive).

Validation of the numerical model based on operational monitoring data should be mandatory for large-scale installations. The observation period should cover at least the first 3 years of operation and should include passive monitoring of observation wells located downstream of the monitored installation.

For medium-sized installations, abovementioned validation and adjustment of the numerical model based on monitoring data should be recommended.

For areas with a high density of installations, it is recommended that local authorities create and regularly update a numerical model at local to regional scale that considers existing installations based on a steady state approximation of the operational parameters (annual thermal work, annual yield) stated in the licenses. This model should be made publicly accessible and used for designing new installations and simulate their impact to avoid biased modelling assumptions.

Table 2: Summary of recommended methods for the design of OLS

	S	M	L
OLS	Simplified analytical approximation	Numerical Simulation recommended	Numerical simulation mandatory

CATALOGUE OF SUCCESS CRITERIA FOR A SUSTAINABLE MANAGEMENT OF SHALLOW GEOTHERMAL USE

ANNEX 4

DRILLING HAZARDS RECOMMENDATION TABLE

Deliverable: D.T2.5.1

Project partner: LP-GBA

03/2019

Special geographical and geological conditions during the installation of shallow geothermal energy systems. Summary of possible consequences and associated recommendations and actions

Geographical and geological topics	Potential consequences for the following components of the environment:				Recommendations and actions
	Groundwater (GW)	Underground/soil	Environment	SGE-System	
Artesian aquifers	Depression, rise of GW, mixing of different groundwater bodies	Soil wetness	Flooding of properties, mud deposition Impact on water-dependent ecosystems - wetlands	More complicated borehole installation due to overpressured conditions	Possible: Limitation of drilling depth Selection of drilling equipment
Very shallow depth to groundwater table		Soil wetness around reinjection site	Influence on biotic components (plants)		Appropriate dimension (flow rate/permeability) of injection well (1.5 – 2 x dimension of extraction well)
Two or more groundwater storeys	Depression, rise of GW, mixing of different groundwater bodies	Ground heaving, depression, soil wetness or dry soil			Limitation of drilling depth or seal of annulus in area of aquiclude/aquitard
Mineral water resources	Impact on existing use (extraction rate, physico-chemical composition)		Contamination of mineral water resources	Scaling of OLS, corrosion of both OLS and CLS	Appropriate selection of grouting material
Thermal water resources	Impact on existing use (extraction rate, physico-chemical composition); Change of chemical equilibrium due to thermal impact	Precipitation or dissolution	Thermal pollution of thermal water resources	Heat damage to material Increased corrosion levels	Select heat resistant and corrosion resistant materials Expert survey to exclude negative impact on existing usages
Gas occurrences	Change of physico-chemical composition by degassing	Gas release	Health issues	Damage to certain materials due to gas diffusion Blow-out	Drilling fluid density selected to ensure overbalanced conditions HSE procedures in place (sensors, training etc.)
Mining areas	Depression, mixing of different groundwater bodies, release of hazardous materials such as heavy metals	Depression, slumps, extensive collapse of subsurface	Pollution of surface waters	Loss of drilling fluid Instability or loss of drilling rig, loss of wellbore due to sloughing	Commissioning of drilling companies with qualified and trained personnel

Contaminated soil	Pollution of groundwater due to ingress of hazardous materials		Release of hazardous gas	Damage to materials due to chemical incompatibility (e.g. hydrocarbons)	Commissioning of drilling companies with qualified and trained personnel
Evaporites	Change of chemical composition	Solution along with depression and slumps; uplift due to swelling of anhydrite		Drilling hazard / higher drilling cost due adapted materials	Commissioning of drilling companies with qualified and trained personnel
Swellable rocks		Uplift due to swelling (of anhydrite)		Drilling hazard (sloughing, swelling) Higher drilling costs due to inhibitive drilling fluid materials and higher disposal volumes	Commissioning of drilling companies with qualified and trained personnel
Karst areas	Depression, mixing of waters, pollutant input	Depression, slump		Lowering of heat extraction capacity, drilling hazards: Loss of drilling fluid, water influx, grouting/sealing difficult due to loss of grouting material	Commissioning of drilling companies with qualified and trained personnel
Water protection area	Contamination, thermal impact on drinking water		Changed thermal conditions – impact on microbiological quality parameters	Contamination of drinking water – consider forbidding all drilling	Implement appropriate restrictions (e.g. materials, minimum distances)
Nature protection area		Very localized soil contamination (e.g. pH change) and ground disturbance	Disturbance of fauna or flora during drilling process	Drilling may be subjected to additional conditions	Consider restrictions during seasonal activities (e.g. breeding) Restrictions on drilling fluid materials and noise levels
Landslide area	Breach: Contamination with heat carrier fluid	Instability, movement		Drilling hazard, potential loss of well/installation	Commissioning of drilling companies with qualified and trained personnel
Faults and highly fractures areas	Depression, rise of groundwater table, mixing of different groundwater bodies	Depression, slump		Drilling hazard (e.g. sloughing, ledges), loss of drilling fluid, grouting/cementing unsuccessful	Well planning (dip/azimuth)

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ANNEX 5

PARAMETERS CONCERNING THE MONITORING OF SGES

Deliverable: D.T2.5.1

Project partner: LP-GBA

03/2019

Parameter explanation for D.T2.5.1 - Chapter 3.5 Monitoring

Operating hours – should be recorded every minute for accuracy; the operating hours form the basis for simple heat production estimates.

Water analysis – the chemical analysis should cover the following parameters: Temperature, pH, Na^{+}, Ca^{2+}, K^{+}, Cl^{-}, $SO4^{2-}$, HCO_3^{+}, Mn^{2+}, dissolved Fe.

Operating pressure – serves as an indicator for leakage of heat carrier fluid.

Volume flow – the volume pumped does not take the temperature dependency of the fluid density into account, but it can be used to approximate the mass flow and derive an estimate for heat flow. Flow meters are simpler and cheaper than mass flow meters.

Mass flow – it is required to calculate an exact value for heat flow.

Electricity consumption – correct placement of the electricity meter is important; all pumps, compressors etc. should be included. Analog electricity meters are a cheaper option than electronic ones.

Temp out – the temperature of the heat carrier fluid / ground water before it enters the heat pump (i.e. not the temperature of the fluid as it exits the well).

Temp in – the temperature of the heat carrier fluid / ground water as it exits the heat pump (i.e. not the temperature of the fluid as it returns at the well head).

Vertical temperature profile – they should be recorded at the beginning and end of the heating period, and ideally 4 x per year in regular intervals. The observation well should be situated downstream of the SGE installation; for large-scale open-loop systems, a second well upstream of the SGE should be measured.

Annual volume pumped – the volume should be recorded for documentation purposes. Together with temp in/out, the heat production can be estimated.