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Recommendations to CEN Technical Working Groups for the technologies developed

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Summary

The document D6.6 “Recommendations to CEN Technical Working Groups for the technologies developed” is a public document delivered in the context of WP6, Task 6.5: *“Implementation of Standards overview and Recommendation on the overcome differences and barriers inside the CEN”*. In this document the relevant standards and guidelines in force today are listed and their implications for the GEO4CIVHIC technologies examined, in order to provide suggestions for adaptation of standards or development of further documents.

In the building sector the setting of appropriate and widely accepted standards is key for reliable quality. The widest coverage for standards in Europe is guaranteed under the CEN label, with EN standards adopted in all CEN member countries. CEN launched in 2017 a new committee CEN/TC451 on “geothermal and water boreholes”, the working group 2 of which did meanwhile draft a standard for Borehole Heat Exchangers (BHE) and is supposed to draft further standards on other shallow geothermal technologies in the future. Findings from the project concerning existing and newly developed BHE technology have been compiled in Task 6.5 and proposed as input for CEN/TC451/WG2 through the existing contacts and involvement of project partners in the respective CEN committee and other standardisation groups. The recommendations thus were brought to the attention of both CEN/TC451/WG2 and other, national standard committees, like the one for VDI 4640 in Germany or for UNE 100715-1 in Spain.

Standards on relevant other items than BHE (further ground coupling methods, drilling and heat pumps) have also been considered and are mentioned in the document. Activity on those fields was not deemed a priority, with an appropriate set of standards already in existence.

As no standardisation activity at European level has covered SGE application to historic buildings yet, nor do any references can be found within existing standards, some consideration is given to this topic in the document.

This document reviews the development and current status of standards and guidelines for SGE in Europe (chapter 2), analyses the relevance for GEO4CIVHIC of such documents (chapter 3), considers the new CEN workshop agreement proposed by the GEOFIT-project (chapter 4), and derives suggestions for future standardisation related to the GEO4CIVHIC results (chapter 5).

The historical development of standards and guidelines for SGE is described in Appendix A, and a list of documents currently in force is given in Appendix B.

Abbreviations

GEO4CIVHIC	Most Easy, Efficient and Low Cost Geothermal Systems for Retrofitting Civil and Historical Buildings
AENOR	Asociación Española de Normalización y Certificación (Spanish Association for Standardization and Certification)
AFNOR	Association française de normalisation (French Standardization Association)
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
AWP	former Arbeitsgemeinschaft Wärmepumpen (Heat Pump Working Group, Switzerland, now defunct)
BAFU	Bundesamt für Umwelt (Federal Office for the Environment, Switzerland)
BfE	Bundesamt für Energie (Federal Office of Energy, Switzerland); today written BFE
BHE	Borehole Heat Exchanger
BRL SIKB	Beoordelingsrichtlijn Stichting Infrastructuur Kwaliteitsborging Bodembeheer (Guideline of Infrastructure Foundation - Quality Assurance Ground Management), NL
BUWAL	former Bundesamt für Umwelt, Wald und Landschaft (Federal Office of Environment, Forestry and Landscape, Switzerland); since 2005 BAFU
CEN	Comité Européen de Normalisation (European Committee for Standardization)
DECC	former Department of Environment, Climate Change and Water (UK); today part of the Department for Business, Energy & Industrial Strategy (BEIS, UK)
DIN	Deutsches Institut für Normung (German Institute for Standardisation)
DVGW	Deutscher Verein des Gas- und Wasserfaches (German Technical and Scientific Association for Gas and Water)
GHE	Ground Heat Exchanger (general term, includes BHE)
GSHP	Ground Source Heat Pump
GSHPA	Ground Source Heat Pump Association (UK)
HP	Heat Pump
HVAC	Heating, Ventilation and Air Conditioning

IDAE	Instituto para la Diversificación y Ahorro de la Energía (Institute for diversification and saving of Energy, Spain)
IGSHPA	International Ground Source Heat Pump Association (USA)
ISO	International Organization for Standardization
LAWA	Länderarbeitsgemeinschaft Wasser (State Working Group on Water, Germany)
NF	Standards of AFNOR (q.v.)
NSAI	National Standards Authority of Ireland
ÖWAV	Österreichischer Wasser- und Abfallwirtschaftsverband (Austrian Water and Waste Management Association)
ÖWWV	former Österreichischer Wasserwirtschaftsverband (Austrian Water Management Association), today ÖWAV
RAL	RAL Deutsches Institut für Gütesicherung und Kennzeichnung (German institute for quality assurance and marking), established 1925 as „Reichs-Ausschuss für Lieferbedingungen“ (Imperial Committee for delivery conditions)
RES	Renewable Energy Sources
SFH	Single Family House
SG	Svenskt Geoenergicentrum (Swedish Geoenergy Centre)
SGE	Shallow Geothermal Energy
SGU	Sveriges Geologiska Undersökning (Geological Survey of Sweden)
SIA	Schweizerischer Ingenieur- und Architektenverein (Swiss Society of Engineers and Architects)
SN	Standards of Schweizerische Normen-Vereinigung (Swiss Association for Standardization)
SP	former Statens Provningsanstalt (National Testing Institute, Sweden); today part of RISE (Research institutes of Sweden)
TRT	Thermal Response Test
UNE	Standards of AENOR (q.v.), also used as alias for AENOR
UNI	Standards of Ente Nazionale Italiano di Unificazione (Italian National Unification)
VDI	Verein Deutscher Ingenieure (Association of German Engineers)
VDMA	Verband Deutscher Maschinen- und Anlagenbau (German Mechanical Engineering Industry Association)

Introduction

Task 6.5 reviews the development and current status of standards and guidelines for SGE in Europe, analyses the relevance for GEO4CIVHIC of such documents, and derives suggestions for future standardisation related to the GEO4CIVHIC results.

The constant increase of GSHP installations in the 1990s and 2000s in several European countries required some regulation and standardisation. Standards and guidelines supported the market growth, with numbers for all of Europe passing the threshold of 100'000 GSHP units per year in 2006/2007. With the financial crisis of 2008, sales numbers and new installations decreased substantially, having recovered to annual numbers of 80'000-100'000 around 2020. The total number of GSHP installed in Europa increased steadily over the past decade (Figure 1) and is estimated to over 2.1 Mio with a total installed heating capacity of more than 30 GW_{th} in 2021 [1]. The future development can hardly be under-assessed, considering the current run on heat pumps as a result of the gas crisis in the wake of the Russian invasion of Ukraine in February 2022.

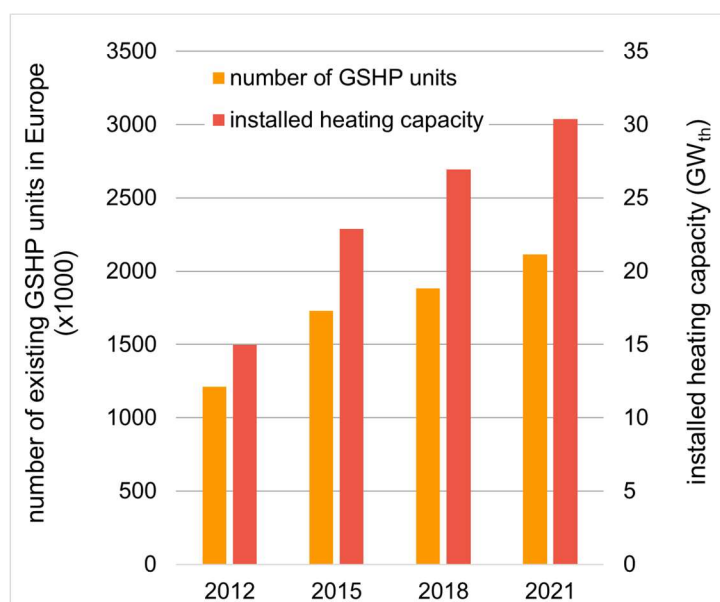


Figure 1 Total number of Ground Source Heat Pump (GSHP) units installed in Europe and estimated total installed heating capacity, after data from the European Geothermal Congresses (EGC) in 2013, 2016, 2019 and 2022.

The development of standards and guidelines was instrumental to achieve this success, and to transform a kind of craft based on the experience of pioneers into the industry we see today. The first GSHP plants were designed and built as individual endeavours, and experience was gained by trial and error. After the first patent on a kind of GSHP from 1912¹, the first true GSHP reported in literature was installed in the USA in Indianapolis in 1945 (a horizontal direct expansion system [2]) and the first GSHP in Europe in Thun, Switzerland, in 1950 (using groundwater wells, reported in [3]).

¹ Swiss patent 59350 of 13.2.1912, inventor Heinrich Zoelly; the main claim reads in translation; 'Heating process, in which an electric motor drives a compressor which forwards a heat carrier medium in a process cycle, the principle of which is equivalent to the process cycle a refrigerant experiences in the operation of a compression cooling machine, and where facilities are foreseen to allow the heat carrier medium to take in heat from the ground.'

The development in Europe continued around 1970 with installations in Germany, Switzerland and Sweden using groundwater wells (e.g. [4]) or horizontal loops ([5], [6]); BHE followed few years later ([7], [8], [9]). BHE were investigated in the early 1980s in the Netherlands [10] and the UK [11] in projects funded by the EU, and a dedicated BHE research installation was supported by the German government in 1985-1989 [12].

Since the 1980s, research on the heat transport in the ground, development of design and sizing methods based on science, investigations into the environmental impact and how to minimise it, and much more related work allowed to replace former “rules of thumb” with clear design criteria and reliable sizing tools. This laid the ground for the standards and guidelines of the 21st century, as described e.g. in [13]. The link between GSHP sales, R&D and standardisation can be seen in the history of the GSHP market in Germany (Figure 2).

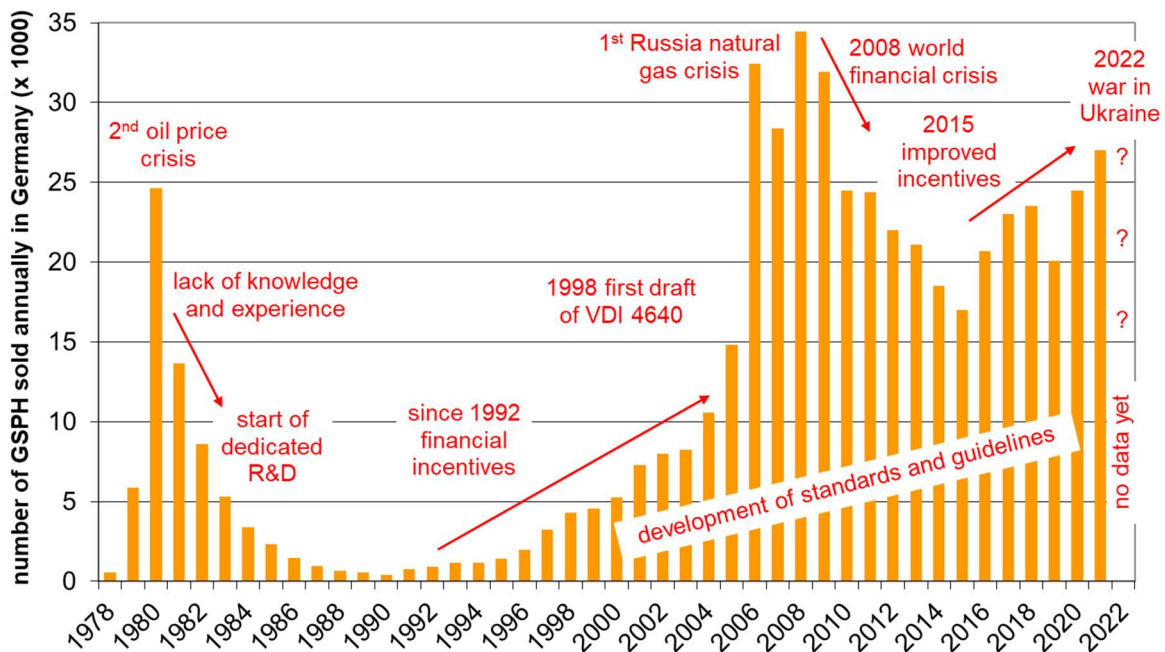


Figure 2 Annual sales numbers of Ground Source Heat Pump (GSHP) in Germany from 1978 to 2021 and factors influencing the development

In Task 6.5 the relevant standards and guidelines in force today were identified, as listed in this deliverable D6.6. The implications of these standards for the GEO4CIVHIC technologies were examined, and the involvement of project partners in the respective CEN committee and other standardisation groups allowed to ensure compatibility of most standards with the evolving technology in GEO4CIVHIC over the full past project lifetime. Thus most issues could be solved already, and only few remaining items are mentioned in this text for further adaptation or new development of standards.

1 Some background on standards/guidelines on SGE

1.1 What are standards/guidelines needed for with SGE ?

Standards are required for ensuring technical soundness of components and installations and adherence to the state-of-the-art. They should assure the customer to receive a safe and efficient product worth paying for, and the authorities to permit an installation safe for the environment. Technical standards need to be accompanied by guidance to the authorities on how to best handle the process for granting a permit to install a GSHP on a certain site with given geological and hydrogeological features. Hence standards and guidelines play a crucial role in the process of issuing permits for installation and operation of GSHP. There are three domains that are relevant for permitting for GSHP in buildings:

1. Correct design and detailed planning for heating/cooling demand (the permitting process will not address comfort, but energy efficiency and avoidance of wasting energy); this permit usually will be part of the building application.
2. For electrically driven heat pumps, the electric power supply is an issue that usually needs a permit by the grid operator, often after some reinforcement of the local power grid or, for larger projects, after building a bespoke transformer substation. In areas with 3-phase grids to buildings this is less often a problem, but insufficient power supply can be a severe barrier in single-phase areas, as highlighted by the example of the UK.
3. Permitting for the heat source (ground collectors, borehole heat exchangers, groundwater wells), with two main aspects:
 - a. Technical aspect: temperatures not too low or too high, avoidance of thermal interference and regional thermal imbalances².
 - b. Environmental aspect: As the protection of soil and groundwater is of paramount importance, risks of pollution or other deterioration need to be avoided. These risks can be associated with digging/drilling, installation, basic hydrogeological risks (e.g. connection of aquifer storeys), thermal risks (in particular with too high temperatures during cooling season) and others.

For the GEO4CIVHIC goals, all three domains are relevant: comfort and efficiency need to be achieved in an already existing building with given characteristics, grid connection has to deal with the constraints of the existing installations, and the ground-side installation must meet the requirements for environmental safety. While some standards for heat pump efficiency are mentioned in this document, the main focus is on standards and guidelines for the ground-side installation and the related permitting issues, also in the case of application in historical buildings.

The ground-side permit process for GSHP must balance two sometimes contradicting sides. It should allow for granting as many permits as possible in a timeframe as short as possible, and it must ensure at the same time that no harm is done to soil, groundwater, presence of historical remains etc. Society and industry cannot afford numerous plants causing environmental problems and groundwater pollution, and in consequence the closing of a promising path towards emission reductions by killing the GSHP industry for good.

² For thermal interference and imbalances, cf. GEO4CIVHIC Deliverable D6.3 “Recommendations for the planning and implementation of new GSHP systems in dense urban environments and related tool” from 29.2.2020.

It is a real challenge to keep said balance, considering the notoriously understaffed authorities in almost all countries. Officers often do not have the necessary information, skills and experience for this specific task, and need support e.g. by relevant guideline documents. The functions of required documents can be classified as follows:

- Documents ensuring the proper design, manufacturing and installation of the ground heat exchangers, including the choice of adequate materials. This concerns both the technical and environmental aspects mentioned above, and pertains mainly to the working field of industry and consultants. Hence standards are usually set by independent organisations (CEN members and other) and under industry leadership, and should also reflect the state-of-the-art of the technology. These standards are not legally binding as such, but could be made mandatory by referring to them in a permit or in legal texts like regulations, decrees, ordinances etc.³
- Documents providing guidance for preventing ground heat exchangers being constructed on sites where no underground disturbance should occur, or on setting individual requirements and restrictions for specific sites to limit a negative impact of SGE installations under the given soil and groundwater conditions. On historical sites, specific factors arising from these circumstances also need to be taken into account. All this is the main work for authorities in SGE permitting, and can be supported by guidelines usually provided by scientific committees under the leadership of governmental authorities. Depending on the character and the issuing entity, these guidelines can either be a nonbinding support for the authorities, or can restrict the ruling of the authority in a legally binding way.

This means the permitting authority concerned (usually water authorities or environmental authorities) can refer to existing standards on GSHP for making sure the technical side will be carried out satisfactorily. For the site-specific environmental aspects, the authority has to give an own assessment and ruling, based on relevant guidelines. Of course, also the legislation in force has to be considered directly by the permitting authorities, either general legislation on water and the environment or specific (usually secondary) legislation on shallow geothermal. Some respective regulations from Belgium, Germany, Italy and the Netherlands are listed in Table B-10 in Appendix B.

1.2 Development of standards/guidelines on SGE

The history of standards and guidelines for SGE is dealt with in more detail in Appendix A; here only a short summary is given. First guideline documents on heat pump use in connection with SGE in Europe were published in the 1980s, primarily considering the impact of this technology on ground and ground water. The first European countries to come up with guidelines were Austria, Germany and Switzerland, where most of the early market development for ground-source heat pumps happened. Astonishingly, no document from a Scandinavian country was found in that period, despite the solid market development in the 1980s/90s in particular in Sweden. Table A-1 in Appendix A lists some early documents.

³ An example from Italy is the new decree of 30 September 2022 of the Ministry of Ecological Transition, containing "*Requirements for the installation of heat production plants from geothermal resources, intended for heating and air conditioning of buildings and simplification for the installation of the aforesaid systems*" and published in the Official Gazette no. 241 of 14 October 2022. In this decree, standard UNI 11517 from 2013 is mentioned explicitly, saying it shall apply for the quality certification of enterprises engaged in the installation of BHE.

Considering the seniority of GSHP application in the USA over Europe (cf. [14] and the sheer number of annual installations in America, the European development definitely was influenced from across the Atlantic. An example for early design and installation guidelines in North America is the manual on GSHP presented by ASHRAE in 1985 [15].

In Europe, a big step forward was the establishment of a dedicated guideline committee on the thermal use of the underground with the German Association of Engineers (VDI) in 1995. The first draft of the resulting guideline VDI 4640 was published in 1998. With the ongoing market growth in many European countries, from about 2005 onwards numerous national guidelines and standards were published (Table 1); the current status as of 2022 is described in chapter 2.2. The trend in Europe, however, is to move standardisation to a more supra-national level within CEN, and hence first standards for the geothermal heat pump sector have been published on the CEN-level in recent years (chapter 2.1).

	1995 [16]	2008 [17]	2022
Standards	7	13	29
Countries	3	4	10 + Europe
	AT, CH, DE	AT, CH, DE, SE	AT, CH, DE, FR, IE, IT, NL, SE, SP, UK and CEN

Table 1 – Number of shallow geothermal standards (only true, dedicated standards) and countries involved 1995-2022

2 Current situation of standards/guidelines on SGE in Europe

2.1 Standards on a European level (CEN)

Through the European Committee for Standardization (CEN) a harmonisation of standards within the EU, EFTA and beyond is intended. Eventually, all national standards shall be replaced by CEN standards (EN) adopted by the national standard organisations, with the same core text (in the respective languages) and the possibility to add some national appendices. Table 2 lists relevant CEN standards for heat pumps. The first CEN standard including some design criteria for GSHP was EN 15450 “Heating systems in buildings - Design of heat pump heating systems”, published as a draft in April 2006 and in a final version in 2007. The standard became effective with the publication of the national versions, e.g. BS EN 15450 in the UK in November 2007, DIN EN 15450 in Germany in December 2007, OENORM EN 1540 in Austria in January 2008, NF EN 15450 in France in January 2009, etc. The standard deals with the planning of heat pump systems in general, and most of the details on ground source are given in appendix A. This appendix is a shortened summary of VDI 4640-2 in the version from 2001. EN 15450 is still valid in the version from 2007.

Another CEN standard related to ground source technology is EN ISO 17628 on Thermal Response Test (TRT, called Geothermal Response Test, GRT, within the document). This standard was developed by geotechnical experts on the basis of a draft guideline from Annex 13 of the IEA energy storage programme, finalised in 2004, published as an appendix in [16], and already far behind the state-of-the-art when EN ISO 17628 was issued in 2015. Hence the most comprehensive and up-to-date document on TRT today is VDI 4640-5 from 2020 (see below).

An effort to create a dedicated standard on ground source heat pumps on the European level was started with the creation of the technical committee TC 451 within CEN in 2016, on an initiative of the French standards organisation AFNOR. The name of CEN/TC 451 was “Geothermal and water boreholes”, and the committee soon was divided into two working groups, WG1 on water boreholes and WG2 on (shallow) geothermal boreholes. Meanwhile, the committee was renamed to CEN/TC 451 “Water wells and borehole heat exchangers”, and WG2 to “Borehole heat exchangers”, to better reflect the topic actually covered by the working group. The first standard elaborated by CEN/TC 451 WG2 is EN 17522 “Design and construction of borehole heat exchangers”, published as draft (prEN 17522) in June 2020. After numerous wishes for changes from national associations and experts, a thorough re-working of the draft was started. The final version might be named “Design and construction of grouted borehole heat exchangers”, in order to not interfere with the Scandinavian practise of pipes in open boreholes without grout. Changes relevant for GEO4CIVHIC are sought in section 6.2.3, defining the use of metallic materials, and section 8.4 concerning exceptions to welded BHE connections for metallic materials. The finalisation of EN 17522 was planned for summer 2022, but has been postponed, and publication can be expected early in 2023.

No standardisation activity at European level has been specifically devoted to SGE application to historic buildings until today, nor are there any references within existing standards, despite publication of numerous reports of successful application (e.g. [19], [20]). Even the dedicated standard for improving the energy performance of historic buildings, EN 16883, does not mention SGE.

Number	Title	Latest version
Standards related to ground source heat pumps		
EN 15450	Heating systems in buildings - Design of heat pump heating systems	2007
EN 15879	Testing and rating of direct exchange ground coupled heat pumps with electrically driven compressors for space heating and/or cooling Part 1: Direct exchange-to-water heat pumps	2011
prEN 17522	Design and construction of borehole heat exchangers	2020
EN ISO 17628	Geotechnical investigation and testing – Geothermal testing – Determination of thermal conductivity of soil and rock using a borehole heat exchanger	2015
Standards on heat pumps in general		
EN 378	Refrigerating systems and heat pumps - Safety and environmental requirements Part 1: Basic requirements, definitions, classification, selection criteria Part 2: Design, construction, testing, marking and documentation Part 3: Installation site and personal protection Part 4: Operation, maintenance, repair and recovery	2016 2016 2016 2016
EN 1861	Refrigerating systems and heat pumps - System flow diagrams and piping and instrument diagrams - Layout and symbols	1998
EN 13313	Refrigerating systems and heat pumps - Competence of personnel	2010
EN 14511	Air conditioners, liquid chilling packages and heat pumps for space heating and cooling and process chillers, with electrically driven compressors Part 1: Terms and definitions Part 2: Test conditions Part 3: Test methods Part 4: Requirements	2018 2018 2018 2018
EN 14825	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	2018
Standards on drilling equipment		
EN 16228	Drilling and foundation equipment	2014
Energy performance of historic buildings		
EN 16883	Conservation of cultural heritage - Guidelines for improving the energy performance of historic buildings	2017

Table 2 – CEN-standards related to ground source heat pumps, heat pumps in general, drilling equipment and energy performance of historic buildings

Several EN standards concern heat pumps in general, but are nevertheless relevant for ground source heat pump systems. There are two main fields of interest: Safety and environmental requirements (dealt with in the for parts of EN 378) and testing and rating (covered in EN 14511 and EN 14825). These and a few more EN standards are also listed in Table 2. Furthermore, there are a number of EN standards on individual components of heat pumps (compressors, valves, safety devices etc.) that are of importance for the heat pump manufacturers, but less so for the system designers and installers, and thus not listed here. Furthermore, regulations apply for the refrigerants in use (environmental issues, in some cases flammability).

EN 16228 is a standard for drilling equipment, concerning mainly the safety of the machinery. Part 2 of this standard addresses explicitly the type of mobile drilling rigs typically used in shallow geothermal installation. Other specific standards for drilling equipment suitable for shallow geothermal could not be found at CEN, while individual components are standardised in the usual way. Drilling and drilling rigs on the whole are not well covered in standardisation, with the deep drilling e.g. for hydrocarbons being an exception; however, most standards in the deep drilling field are set by the American Petroleum Institute (API) and not applicable to shallow geothermal. Some helpful material exists, however, on the national level, e.g. with guidelines provided by DVGW in Germany.

In addition, some ISO standards concerning heat pumps and drilling equipment are also valid throughout Europe and beyond. As the target of Task 6.5 was on the CEN and national level and direct contact with ISO did not exist, no further action was taken. ISO standards are included in Tables B-3 and B-4 in Appendix B; there is some common coverage and similarity between the ISO standards mentioned, e.g. ISO 5149 on heat pump is similar to EN 378. In some cases there are even joint standards between ISO and EN, like EN ISO 17628 on TRT.

2.2 Standards and guidelines on national levels

Currently national standards and guidelines can be reported from 10 countries in Europe (Table 3). The countries first coming up with guidelines and standards (Austria, Germany, Switzerland; cf. chapter 1.2) meanwhile have updated and enlarged versions. France and Italy each have a small series of standards covering different aspects and several types of GHE. In Spain a specific standard on BHE exists, while more general standards on GSHP are in force in Ireland, the Netherlands, Sweden and the United Kingdom. On national level, no standardisation activity has been specifically devoted to SGE application to historic buildings in any European country yet, nor are there any references within existing standards.

The most comprehensive set of design and installation guidelines currently in force is VDI 4640 from Germany. From the first drafts in 1998, the series evolved into five parts covering

- fundamentals, approvals, environmental aspects (part 1, latest version from 2010, with a draft revision published in 2021),
- ground source heat pump systems (part 2, 2019),
- underground thermal energy storage (part 3, 2001),
- direct uses (part 4, 2004) and
- thermal response test (part 5, 2020).

A part 6 on grouting materials is under preparation. As VDI is not a member of CEN, the VDI guidelines will not be affected by upcoming EN standards and will continue providing a more detailed guide to correct shallow geothermal design and installation.

Country	Number	Title in English	Latest version
AT	ÖWAV RB 207	Thermal use of groundwater and underground - Heating and cooling	2009
CH	SN 546 384/6 SN 546 384/7	Borehole heat exchangers Use of the heat of the groundwater	2021 2015
DE	DIN 8901 DVGW W 120 VDI 4640	Refrigerating systems and heat pumps - Protection of soil, ground and surface water Qualification requirements for the sector of drilling technology, 2 parts Thermal use of the underground, 5 parts (see text)	2002 2012-13 2001-21
FR	NF X10-950 NF X10-960 NF X10-970 NF X10-999	Geothermal energy drilling - Grouting for closed vertical geothermal exchanger Boreholes for water and geothermal - vertical borehole heat exchangers, 4 parts (general, 3 different pipe materials) Boreholes for water and geothermal - vertical borehole heat exchangers - Installation, commissioning, maintenance, abandonment Boreholes for water and geothermal - operation, supervision and abandonment of groundwater wells for extraction or monitoring	2018 2013 2011 2014
IE	NSAI S.R. 50-4	Building services — Code of practice — Part 4: Heat pump systems for dwellings	2021
IT	UNI 11466, 11467, 11468 UNI/TS 11487 UNI 11517	Geothermal systems with heat pump (3 parts on design, installation and environment) Geothermal systems with heat pump – requirements for the installation of direct expansion systems Geothermal systems with heat pump – requirements for qualification of companies installing geothermal heat exchangers	2012 2013 2013
NL	BRL SIKB 11000	Design, realisation, operation and maintenance of the subsurface part of shallow geothermal installations	2014-2015
SE	Normbrunn-16 SG SG	SGU, Guideline for drilling of wells Guidelines for Thermal Response Test (TRT) Guidelines for measurements and monitoring in shallow geothermal energy systems	2016 2015 2018
SP	UNE 100715-1	Design, installation and maintenance of shallow geothermal installations - closed vertical systems	2014
UK	DECC MIS 3005 DECC MCS 022 GSHPA GSHPA GSHPA GSHPA	Requirements for contractors undertaking the supply, design, installation, set to work commissioning and handover of microgeneration heat pump systems Sizing tables for ground heat exchangers systems Good practice guide for ground source heating and cooling Vertical Borehole Standard Thermal Pile - Design, Installation & Materials Standards Shallow Ground Source Standard	2017 2011 2017 2017 2012 2018

Table 3 – National-standards in Europe related to ground source heat pumps

Published by national standardisation organisations are the standards in France, Ireland, Italy and Spain (cf. Table 3). In the long term, these documents will be replaced by respective CEN standards adopted into national ones. Hence most of the work on national standards is halted and national experts contribute to CEN activities like CEN/TC 451 WG2 (chapter 2.1). Exceptions are Switzerland with a new version of the highly respected standard SN 546 384/6 on borehole heat exchangers in 2021 and Ireland with NSAI S.R. 50-4 also published in 2021. The Irish standard gives guidelines for the design, installation, commissioning, and maintenance of heat pump systems with an effective rated output up to 70 kW in new and existing dwellings. The document now is the main reference for BHE system in Ireland and comprehensively cross-references design and installation of BHEs to EN 17522.

The guideline documents in Austria, Germany, the Netherlands, Sweden and the UK are expected to continue being valid and updated alongside any CEN standards adopted in the respective countries, and add some national details and specialities. It is, however, important to ensure that such national documents and CEN standards are not contradictory in their wording. A standard on the CEN level is not necessarily more accurate or up-to-date as a national document, as the case of EN ISO 17628 exemplifies.

3 Implications from standards and guidelines on GEO4CIVHIC technology

3.1 Situation of (pr)EN 17522 and implications for GEO4CIVHIC technology

The draft standard prEN 17522 “Design and construction of borehole heat exchangers” was published in June 2020. After numerous wishes for changes from national associations and experts, a thorough re-working of the draft was done. The finalisation of EN 17522 was planned for summer 2022, but has been postponed, and publication can be expected early in 2023. The final version might be named “Design and construction of grouted borehole heat exchangers”, in order to not interfere with the Scandinavian practise of pipes in open boreholes without grout.

From the 2020 draft, changes relevant for GEO4CIVHIC were sought in section 6.2.3, defining the use of metallic materials, and section 8.4 concerning exceptions to welded BHE connections for metallic materials. Without pre-empting the upcoming release of EN 17522, it can be expected that the required changes will be in the final text. As this standard concerns BHE only, no further action seems necessary.

3.2 Relevance of national standards/guidelines for GEO4CIVHIC

A basic feature in most national standards on BHE (outside Scandinavia) is the requirement of factory-welded pipe connections, at least in the part of the loop to be inserted into the borehole, and the mandatory grouting of the borehole annulus. Some of the technologies demonstrated in GEO4CIVHIC, however, require pipe connections made on the drilling site or do not need (or do not allow for) grouting.

VDI 4640-2 from 2019 can serve as an example. It was stipulated therein that all pipe joints in the subsurface must be welded (incorrectly translated as “directly bonded” in the English text of VDI 4640-2). This would have been incompatible with some GEO4CIVHIC procedures. In April 2020 a 3-page correction to VDI 4640-2 from 2019 was published, just saying “all joints must be permanent”, not asking how that is achieved. In the current version this pertains to all pipe connections in the subsurface with the exception of those at the BHE foot, or any possible connection within the vertical part of the BHE. Also grouting of the borehole annulus is mandatory as to VDI 4640-2. This means that the text still contains some marginal obstructions for certain part of GEO4CIVHIC technology.

4 CEN Workshop Agreement proposed by GEOFIT project

In March 2022 a new CEN Workshop Agreement was proposed by UNE on behalf of the consortium of the GEOFIT project (H2020 GA No. 792210). It currently is listed as prCWA XXXX:2022 (no number yet, as of 25.11.2022) under the title “Guidelines for an integrated approach of building retrofitting projects based on enhanced shallow geothermal technologies”. This proposal is explained in this chapter and possible actions for GEO4CIVHIC are discussed.

The topical areas behind the Workshop Agreement draft are those of the GEOFIT project:

- Information and communication technologies (ICT) tools for ground research and worksite monitoring.
- Drilling technologies adapted to the context of SGE building retrofitting.
- Geothermal/ground source heat exchangers (GHE) with corresponding suitable configurations for SGE building retrofitting and effective installation (vertical borehole type heat exchangers, earth basket and helical type heat exchangers, shallow horizontal or slinky type heat exchangers).
- Ground Source Heat Pumps (GSHPs) optimized for the use of geothermal heat and building retrofit applications (hybrid, i.e. thermally and electrically driven heat pump system for high temperature lifts, electrically driven HP system for high temperature lifts, and Integration of other RES like photovoltaic and solar thermal to increase the total RES share).
- Heating and cooling solutions for energy-efficient building retrofitting ICT based control systems and building energy management systems.
- Building Information Modelling enabled tools for management of SGE building retrofitting

In particular the areas of GHE and heat pumps overlap with the work of the GEO4CIVHIC project. The Workshop Agreement, however, does not address the technical side of the GEOFIT developments, but the management of a refurbishment process with SGE. This is stated in chapter 1 of the draft:

“This CEN Workshop Agreement (CWA) provides orientation for the management of building retrofitting projects based on enhanced shallow geothermal technologies. This document provides guidelines for the classification of an integrated design team and the identification of the primary roles of actors among the whole project life-cycle. This document also provides a general workflow for building retrofitting projects based on enhanced shallow geothermal technologies, to be adapted or modified considering the specificities of each project requirements, and site characteristics, and stakeholder profiles involved in the process.”

The draft then deals with the selection of an integrated project design team and explains the roles of clients, designers, contractors and managers. There is a chapter focused on defining main phases and identifying primary roles in the SGE building retrofitting project, and finally the developing of a collaborative workflow schedule is explained, including a sample flowchart.

The use of a CEN Workshop Agreement to cover an integrated topic seems advantageous, as it does not require the full scrutiny by CEN members and thus can be prepared much quicker. The fact that UNE (AENOR) is a GEOFIT consortium partner has helped here obviously. For GEO4CIVHIC it might be interesting to use the SGE management approach as presented, make necessary adaptations and suggest those for a future update of the document.

For the technical side, the CEN Workshop Agreement prepared by GEOFIT does not give any help and information. It might be interesting to consider another CEN Workshop Agreement to be suggested from the GEO4CIVHIC consortium, dealing with the technical aspects, and inviting GEOFIT partners and others (e.g. from former projects GEOCOND or Cheap-GSHPs) to develop it jointly.

A CEN Workshop Agreement could also be a vehicle to bring the GEO4CIVHIC results on SGE in historical buildings into the standardisation realm. As a specific document on historical buildings is planned in GEO4CIVHIC (D6.7, Transferrable guideline for the integration of GSHP systems to historical buildings, due month 63 / June 2023), this could serve as a basis for a wider discussion with other related projects and players in a dedicated activity for a respective CEN Workshop Agreement.

As the draft prCWA XXXX:2022 (GEOFIT) was published only recently, the GEO4CIVHIC consortium did not yet have time to scrutinise the text and to prepare their own suggestions. Also a discussion and decision on own proposals on technical aspects and/or on SGE for historic buildings could not yet be done, and will not be possible before the deadline for document D6.6. Hence any decisions and further development will have to be reported separately at a later date. Possible activities for CEN Workshop Agreements would not necessarily be part of the GEO4CIVHIC project and thus would not be limited by the project lifetime.

5 Suggestions for future activities in CEN and national frameworks

On the CEN level, EN 17522 on BHE needs to be further scrutinised and possibly updated in future in order to keep it reflecting the state-of-the-art. This could include further evolutions of the GEO4CIVHIC technologies. National annexes or supplements should be considered (see below). For the Scandinavian practice of open boreholes in solid rock (no grouting), either a dedicated equivalent to EN 17522 or a national supplement could be prepared. As EN 17522 is focusing on classical BHE only, standards on other ground-coupling methods than BHE, such as well-point-type GHE, helicoidal BHE or any other type of GHE, might be developed. This probably would require either a change in the area covered by CEN/TC 451 WG2, which by name is intended for everything with “boreholes”, or the creation of another CEN/TC explicitly tasked with all aspects of SGE technology.

In the field of heat pumps the structure for standardisation is well established on the CEN level, with most national standards meanwhile replaced by EN standards. The further development and updating of the existing standards is in safe hands, and no specific suggestions from GEO4CIVHIC are deemed appropriate.

The gaps in EN standards on shallow geothermal drilling equipment and operation should be filled in, e.g. using some of the German DVGW guidelines as a starting point. This ought to include the Vibro-Drill method⁴ for drilling, and both the TKI and Hydra-RED methods for BHE completion⁵, all part of GEO4CIVHIC. The results at the end of the project will allow to determine what part of the development can be applied successfully, and will provide the necessary information to draft the respective paragraphs for a drilling standard.

For the individual CEN members it will be important to prepare national annexes or even create some national supplements in order to cover typical practice in the individual countries. An example from Austria for such a document is OENORM M 7755 “Heat pump heating systems - Requirements for design and installation” from 2008, which complements EN 15450 on the design of heat pump heating systems from 2007 (or, more precisely, OENORM EN 15450 from 2008). A national supplement to EN 17522 on BHE in Belgium might e.g. include the Geo-Green method to use steel-tube coaxial BHE without grouting. Also the TKI and Hydra-RED methods for BHE completion could be part of national supplements to EN 17522.

Purely national standards and guidelines will not lose their justification. The most influential one is VDI 4640, and thus the GEO4CIVHIC technologies should be covered therein, as mentioned above for the national annexes/supplements to EN 17522. As stated in chapter 3.2, there are still some marginal obstructions for certain part of GEO4CIVHIC technology in VDI 4640-2. For the national or regional guidelines concerning the permitting of SGE installations (cf. Tables B-5, B-6 and B-7 in Appendix B), no specific action is required. For the technical part, these guidelines usually refer to the respective standards, and thus new technologies will be covered implicitly once they become part of updated standards.

⁴ Vibro-Drill is technology of terra infrastructure GmbH, formerly Thyssenkrupp Infrastructure GmbH (TKI) and still listed under that acronym within the GEO4CIVHIC project; a standard including that technology should address also methods based in similar principles, like sonic drilling.

⁵ These completion technologies are not yet published, and will be included in a later, public deliverable; for the meaning of TKI, see the preceding footnote, Hydra and RED are two other GEO4CIVHIC project partners.

As no standardisation activity at European level has covered SGE application to historic buildings yet, nor can any references be found within existing standards, some dedicated work on this field is deemed crucial for a wide application of SGE in the built environment. A possible path towards targeted standardisation could be a CEN Workshop Agreement (cf. chapter 4), that might later lead to a full CEN standard.

6 Conclusions

The availability of national standards and guidelines on SGE has improved greatly over the last decade. The range of ground-coupling technologies and technical areas covered did increase also. For BHE, a harmonisation on the European level and standardisation for countries not yet having national documents is under way with the upcoming EN 17522.

Suitable technical standards for design and installation of GSHP exist since more than 20 years, with VDI 4640 in Germany and SIA 384/6 (later SN 546 384/6) in Switzerland. VDI 4640 covers all varieties of shallow geothermal energy use in 5 parts, while in Switzerland SN 546 384/6 concerns BHE and SN 546 384/7 groundwater wells for heat pumps. Meanwhile, technical standards on all or part of GSHP exist also in

- France (NF X10-960 and NF X10-970),
- the Netherlands (BRL SIKB 11000),
- Ireland (NSAI S.R. 50-4),
- Italy (UNI 11466, 11467, 11468 and 11487),
- Spain (UNE 100715-1),
- Sweden (Normbrunn-16 and some material from SG)
- and the UK (DECC MIS 3005, MCS 022, and material from GSHPA).

For all other countries, and overriding some of the existing standards on BHE, a European standard (CEN) is expected soon with EN 17522 on (grouted) BHE; publication will probably be made early in 2023.

Guidelines for site evaluations and environmental issues of GSHP exist since about 1980 and thus pre-date the technical standards. The first guideline from LAWA (a working group of German state water authorities) was published in 1980 and last updated in 2011. Similar guidelines were issued in Austria in 1986 (ÖWAV) and in Switzerland in 1994 (BUWAL).

To help with the interpretation of the regional geological and hydrogeological situation and to outline possible other constraints (e.g. groundwater protection areas around water wells for drinking water), thematic maps have been compiled by relevant authorities (usually geological surveys). The first map of areas suitable (or prohibited) for GSHP was published by the canton Bern in Switzerland in the mid 1990s, printed on paper. The German state of North Rhine-Westphalia provided the first digital map for GSHP use on a CD-ROM around the year 2000. Today numerous guidelines and maps exist on different administrative levels, with maps usually provided on web-based GIS, including the (updated) one for the canton Bern. Several EU-projects, the latest being MUSE⁶ (Managing Urban Shallow geothermal Energy), have contributed to the integration of data on GSHP potential and risks. The MUSE map-viewer is meanwhile adapted to the framework of EGDI (European Geological Data Infrastructure).

In countries with established GSHP markets, guidelines and maps are typically available today (tables on state-level guidelines in Austria, Germany and Switzerland are provided in Appendix B), while for other countries some overarching, basic environmental guidance for GSHP use is desirable. Switzerland in particular has a wealth of information available to applicants for GSHP installations (Tables B-8 and B-9 in Appendix B), including application templates with explanations; application forms are also part of some of the state guidelines in other countries.

⁶ <https://geoera.eu/projects/muse3/>

As to maps, it can be hoped that the past work will be extended to new areas, and all relevant regions of Europe will be covered one day.

In the standards and guidelines analysed within Task 6.5 no obvious contradiction concerning GEO4CIVHIC technologies was detected. A substantial involvement of GEO4CIVHIC partners in relevant standardisation committees exists, sometimes dating back decades, and their efforts ensured that technologies like the special BHE further developed within GEO4CIVHIC are treated fairly in the documents.

Some suggestions are made in chapter 5 for additional standardisation, including new CEN standards for other SGE technologies and for drilling equipment and operation, and to start some activity towards a dedicated standard on SGE application to historic buildings. Furthermore, it is suggested to use the option of national annexes or supplements to EN 17522 to cover aspects from GEO4CIVHIC development.

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Title page of Cheap-GSHPs project report on historic buildings

Appendix A: History of guidelines on SGE since the 1980s

A.1 Early standards and guidelines on SGE in Europe

The first guideline documents on heat pump use in connection with shallow geothermal energy in Europe were published in the 1980s, considering mainly the impact of this technology on ground and ground water. In the late 1970s, groundwater wells and horizontal loops were the main technologies used [A1], and thus concerns about thermal impact on the groundwater and leakage of working fluids were of concern.

The first countries to come up with guidelines were Austria, Germany and Switzerland, where most of the early market development for ground-source heat pumps happened. Table A-1 lists these early documents, shortly described below. In 1995, a paper within the IEA heat pump programme [A2] could identify just 7 guidelines and standards from the 3 countries mentioned above; astonishingly, no document from a Scandinavian country was found at that time, despite the solid market development in the 1980s/90s in particular in Sweden.

Year	Country	Original Title	Title in English	Published by
1980	DE	Grundlagen zur Beurteilung des Einsatzes von Wärmepumpen aus wasserwirtschaftlicher Sicht	Fundamentals for evaluating the use of heat pumps in the view of water management	LAWA, ZfGW-Verlag, Frankfurt
1982	CH	Die vertikale Erdsonde als Energiebeschaffungssystem	The vertical borehole heat exchanger as a system to collect energy	BfE, Studie EPA Nr. 217.184, Bern/Zurich (by Schwanner & Hopkirk)
1983	DE	1. Ergänzung zu Grundlagen zur Beurteilung des Einsatzes von Wärmepumpen aus wasserwirtschaftlicher Sicht	1 st addition to Fundamentals for evaluating the use of heat pumps in the view of water management	LAWA, ZfGW-Verlag, Frankfurt
1986	AT	Wasserwirtschaftliche Gesichtspunkte für die Projektierung von Grundwasserwärmepumpenanlagen	Water management aspects of planning for ground water heat pump systems	ÖWWV-Arbeitsbehelf 03, Vienna
1988	CH	Base de dimensionnement des systèmes exploitant la chaleur du sol à basse température	Fundamentals for dimensioning of systems extracting earth heat at low temperatures	SIA, Document D 025, Zurich
1989	CH	Erdwärmesonden-Heisanlagen, durch Messungen und Berechnungen bestimmte Auslegungs- und Betriebsgrößen	Heating systems with borehole heat exchangers, design and operation parameters as determined by measurements and calculation	Schriftenreihe des BfE Nr. 46, Bern (by Burkart, Hopkirk, Eugster & Rybach)
1992	CH	Wärmepumpenheizungsanlagen mit Erdwärmesonden	Heat pump heating systems with borehole heat exchangers	AWP Merkblatt T1, Zurich

Table A-1 – Early guideline documents on ground source heat pumps from the 1980s

In **Germany**, where water management regulations are given by authorities on the state level (*Bundesland*), a joint working group of the state authorities (LAWA) agreed on some fundamentals for the harmonised handling of such regulation. In LAWA (1980) mainly groundwater heat pumps are covered. However, an early version of coaxial BHE is also shown. In 1983 a first addition to the LAWA paper was published, covering absorption heat pumps, heat pipes as BHE (one of the early records of this technology), and an updated list of heat pump working fluids. On the technical side for planning and installation, a guide for planning and installation of coaxial BHEs of the type shown in LAWA (1980) was given by a manufacturer [A3], including sizing recommendations and an early version of an on-site test for the thermal yield of the BHE in a given geology.

In **Austria**, the first guideline document has been issued in 1986 by the Austrian Water Management Association, ÖWWV (today ÖWAV), considering ground water heat pumps. The focus was mainly on groundwater protection.

In **Switzerland**, issuing guidelines started with a collection of design criteria by the Swiss Association of Engineers and Architects (SIA) in 1988 and a manual on borehole heat exchangers issued by the Federal Office of Energy (BfE) in 1989. The first proper technical guideline, AWP Merkblatt T1, was published in 1992 by the Swiss industry association Arbeitsgemeinschaft Wärmepumpen (Heat Pump Working Group) in Zurich, and was followed by environmental guidelines provided by the respective Swiss Federal Office (BUWAL) in 1994. AWP Merkblatt T1 was the first in Europe to

- call for factory-produced BHE loops,
- specify a minimum distance of 5 m between BHE,
- and stipulate grouting of the borehole annulus by pumping grout down to the bottom of the borehole in a pipe and filling the annulus from bottom to top.

AWP developed a full set of documents, covering all ground coupling methods (and in addition the use of surface water), with the latest and last version issued in 2007 (Table A-2). Today, AWP does no longer exist, and the AWP guidelines are no longer required, superseded by the Swiss standards SN 546 384/6 and SN 546 384/7 (cf. chapter 2.2).

Name/Number	Title original	Title English
AWP Merkblatt T1	Wärmepumpenheizungsanlagen mit Erdwärmesonden	Heat pump heating systems with borehole heat exchangers
AWP Merkblatt T2	Wärmepumpenheizungsanlage mit horizontalen Erdkollektoren, Erdwärmekörben und Kompaktkollektoren	Heat pump heating systems with horizontal ground heat exchangers, earth heat baskets and compact collectors
AWP Merkblatt T3	Wärmequellennutzung Grundwasser	Use of groundwater as heat source
AWP Merkblatt T5	Füllen von Erdwärmesondenanlagen	Filling of BHE installations

Table A-2 – List of last issues in 2007 of Swiss AWP guidelines concerning GSHP

A.2 Early documents from North America

Considering the seniority of GSHP application in the USA over Europe (cf. [A1]) and the sheer number of annual installations in America, the European development definitely was influenced from across the Atlantic. On the technical side this happened mainly through cooperation within

the IEA heat pump programme⁷. An example for early design and installation guidelines in North America is the manual on GSHP presented by ASHRAE [A4]. Intended for practical use and presenting numerous easy-to-understand drawings was [A5], a “manual of accepted practices” prepared for regional utilities Niagara Mohawk Power Corp. and Rochester Gas and Electric Corp. The National Water Well Association published a handbook on earth-coupled heat transfer [A6] for a more sophisticated and reliable design of GSHP, and to offer design methods better than rules of thumb.

In 1987, the International Ground Source Heat Pump Association (IGSHPA) was founded in Stillwater OK. Already in 1988 IGSHPA presented a first guide to GSHP installation [A7], under the umbrella of the National Rural Electric Cooperative Association. An IGSHPA standards committee was established in 1994, and today IGSHPA standards are accepted practice throughout North America, with the latest version of the standards brochure published in 2017. A breakthrough was in 2016, when the standardisation bodies of both the USA (ANSI) and Canada (CSA) issued a joint, comprehensive set of standards⁸ as ANSI/CSA/IGSHPA C448-16, covering the full field of GSHP applications (Table A-3). Now a single set of rules apply across North America, something not yet fully achieved in Europe.

NB: North American standards cannot be transferred directly to Europe, as the building tradition, regulatory framework, predominant heat pump technology, environmental considerations etc. diverge substantially from the typical European practice.

Number	Title
C448.0	Design and installation of ground source heat pump systems - Generic applications for all systems
C448.1	Design and installation of ground source heat pump systems for commercial and institutional buildings
C448.2	Design and installation of ground source heat pump systems for residential and other small buildings
C448.3	Installation of vertical configured closed-loop ground source heat pump systems
C448.4	Installation of horizontal configured closed-loop ground source heat pump systems
C448.5	Installation of surface water (including submerged exchangers) heat pump systems
C448.6	Installation of open-loop systems ground water heat pump systems
C448.7	Installation of standing column well heat pump systems
C448.8	Installation of direct expansion heat pump systems

Table A-3 – Subsections of North American standard ANSI/CSA/IGSHPA C448-16 “Design and installation of ground source heat pump systems for commercial and residential buildings”

A.3 Start of VDI 4640 and further European development

On European soil, a big step forward was the establishment of a dedicated guideline committee on the thermal use of the underground at the German Association of Engineers (VDI) in 1995. This was done at an initiative of the German Geothermal Association, and the committee brought

⁷ <https://heatpumpingtechnologies.org/>

⁸ <https://igshpa.org/standards/>.

together geologists, heat pump specialists, drillers, HVAC engineers and representatives from relevant authorities. A first draft of the resulting guideline VDI 4640 was published in 1998 and eventually became an authoritative document not only in Germany, but in most of mainland Europa. It did set in motion the creation of numerous national guidelines and standards from about 2005 onwards. In 2008 already 13 documents from 4 countries could be listed [A8], with Sweden joining the three countries with standards reported in 1995 [A2]. Table 1 in chapter 1.2 compares the situation in 1995, 2008 and today (2022), with the current status as of 2022 being described in chapter 2.2 of this deliverable. With the standardisation in Europe moving to a more supra-national level within CEN, also for the geothermal heat pump sector first standards on the CEN-level have been published in recent years (chapter 2.1).

Guideline documents on permitting and environmental protection (primarily groundwater protection) have been developed on the level of states in Austria and Germany, and by cantons, respectively, in Switzerland. The need for support for local and regional authorities tasked with the permitting process was felt urgently in these countries at the end of the 1990s, with markets growing rapidly. Unclear and sometimes difficult application processes and seemingly arbitrary decisions often hindered the installation of new GSHP plants. Industry and the German Geothermal Association (GtV, today BVG) lobbied on the state level (*Bundesländer*) in Germany for some guidance for the authorities, as water regulation is a matter for the states. The first success was with the state of Baden-Wuerttemberg, where after a meeting with the responsible minister in October 1996 (Figure A.1) the drafting of a guideline document was started.



Figure A.1 Meeting of the president and vice-president of GtV and industry representatives with the Minister for Environment and Traffic of Baden-Wuerttemberg Hermann Schaufler (centre) in Stuttgart on 22.10.1996, resulting in the decision to draft a first guideline for SGE permitting in Germany.

The guideline in Baden-Wuerttemberg was published in 1998, the same year that saw the first draft of VDI 4640, and thus a technical standard on GSHP and a guideline on permitting of BHE could complement each other. Further guidelines in other German states and in some Austrian states did follow soon. Today guidelines and maps are typically available in countries with established GSHP markets, either nationally or on a regional/state level (tables on state-level guidelines in Austria, Germany and Switzerland are provided in Appendix B).

To help with the interpretation of the regional geological and hydrogeological situation and to outline possible other constraints (e.g. groundwater protection areas around water wells for drinking water), thematic maps have been compiled by relevant authorities (usually geological surveys). The first map of areas suitable (or prohibited) for GSHP was published by the canton Bern in Switzerland in the mid 1990s, printed on paper. The German state of North Rhine-Westphalia provided the first digital map for GSHP use on a CD-ROM around the year 2000. Today numerous guidelines and maps exist on different administrative levels, with maps usually provided on web-based GIS, including the (updated) one for the canton Bern. Several EU-projects, the latest being MUSE⁹ (Managing Urban Shallow geothermal Energy), have contributed to the integration of data on GSHP potential and risks. The MUSE map-viewer is meanwhile adapted to the framework of EGDI (European Geological Data Infrastructure). The guidelines on permitting thus are supported by access to the relevant site data (geological and other) to evaluate the underground situation along the lines provided in the guideline documents.

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⁹ <https://geoera.eu/projects/muse3/>

Appendix B: List of Standards and Guidelines

Country	Number	Title in English	Latest version
Europe	EN 15450	Heating systems in buildings - Design of heat pump heating systems	2007
	EN 15879	Testing and rating of direct exchange ground coupled heat pumps with electrically driven compressors for space heating and/or cooling Part 1: Direct exchange-to-water heat pumps	2011
	prEN 17522	Design and construction of borehole heat exchangers	2020
	EN ISO 17628	Geotechnical investigation and testing – Geothermal testing – Determination of thermal conductivity of soil and rock using a borehole heat exchanger	2015
AT	ÖWAV RB 207	Thermal use of groundwater and underground - Heating and cooling ¹	2009
CH	SN 546 384/6	Borehole heat exchangers	2021
	SN 546 384/7	Use of the heat of the groundwater	2015
DE	DIN 8901	Refrigerating systems and heat pumps - Protection of soil, ground and surface water	2002
	VDI 4640	Thermal use of the underground - part 1: Fundamentals, approvals, environmental aspects - part 2: Ground source heat pump systems - part 3: Underground thermal energy storage - part 4: Direct uses - part 5: Thermal response test	2010 ² 2019 2001 2004 2020
	NF X10-950	Geothermal energy drilling - Grouting for closed vertical geothermal exchanger	2018
	NF X10-960	Boreholes for water and geothermal - vertical borehole heat exchangers 1 - General issues 2 - Pipe loops of polyethylene 100 (PE 100) 3 - pipe loops of cross-linked polyethylene (PE-X) 4 - pipe loops of polyethylene with higher temperature resistance (PE-RT)	2013 2013 2013 2013
	NF X10-970	Boreholes for water and geothermal - vertical borehole heat exchangers - Installation, commissioning, maintenance, abandonment	2011
FR	NF X10-999	Boreholes for water and geothermal - operation, supervision and abandonment of groundwater wells for extraction or monitoring	2014

¹ In addition ÖWAV-Arbeitsbehelf 43 "Guideline on the use of the formula for thermal dispersion from ÖWAV-RB 207" from 2014

² draft of revised version published in 2021

Table B-1 – Standards and guidelines on ground source heat pumps currently in force in Europe
(continued on next page)

Country	Number	Title in English	Latest version
IE	NSAI S.R. 50-4	Building services — Code of practice — Part 4: Heat pump systems for dwellings	2021
IT	UNI 11466	Geothermal systems with heat pump – requirements for the dimensioning and design	2012
	UNI 11467	Geothermal systems with heat pump – requirements for installation	2012
	UNI 11468	Geothermal systems with heat pump – environmental requirements	2012
	UNI/TS 11487	Geothermal systems with heat pump – requirements for the installation of direct expansion systems	2013
	UNI 11517	Geothermal systems with heat pump – requirements for qualification of companies installing geothermal heat exchangers	2013
NL	BRL SIKB 11000	Design, realisation, operation and maintenance of the subsurface part of shallow geothermal installations	2014-2015
SE	Normbrunn-16	SGU, Guideline for drilling of wells	2016
	SG	Guidelines for Thermal Response Test (TRT)	2015
	SG	Guidelines for measurements and monitoring in shallow geothermal energy systems	2018
SP	UNE 100715-1	Design, installation and maintenance of shallow geothermal installations - closed vertical systems	2014
UK	DECC MIS 3005	Requirements for contractors undertaking the supply, design, installation, set to work commissioning and handover of microgeneration heat pump systems	2017
	DECC MCS 022	Sizing tables for ground heat exchangers systems ³	2011
	GSHPA	Good practice guide for ground source heating and cooling	2017
	GSHPA	Vertical Borehole Standard	2017
	GSHPA	Thermal Pile - Design, Installation & Materials Standards	2012
	GSHPA	Shallow Ground Source Standard	2018

³ relating to DECC MIS 3005

Table B-1 (continued) – Standards and guidelines on ground source heat pumps currently in force in Europe

Country	Number	Title in English	Latest version
CH	BAFU UV 0910	Heat use from soil and underground. Handling guideline for authorities and experts in the geothermal sector	2009
	BUWAL	Fluids hazardous for water: Guide-lines for heat extraction with closed borehole heat exchangers	1994
	SIA D 0190	Use of earth heat with foundation piles and other concrete building parts in contact with the ground	2005
DE	LAWA	Recommendations of LAWA for water-management requirements for BHE and horizontal GHE	2011
	RAL-RG 911	Quality requirements for shallow geothermal installations - Borehole Heat Exchangers - RAL-registration	2014 ¹
SE	Geotec/SP	Manufacturing standard for borehole heat exchangers	2005
SP	IDAE guide 14	Technical guideline for design of geothermal heat exchanger system with closed circuit	2012

¹ the document is still marked as valid, while the respective RAL quality certification seems no longer to exist

Table B-2 – Additional guideline documents on ground source heat pumps currently in force in Europe

Country	Number	Title in English	Latest version
World	ISO 5149	Refrigerating systems and heat pumps - Safety and environmental requirements Part 1: Definitions, classification and selection criteria Part 2: Design, construction, testing, marking and documentation Part 3: Installation site Part 4: Operation, maintenance, repair and recovery	2014 ¹ 2014 ² 2014 ³ 2014 ⁴
	ISO 13256	Water-source heat pumps - Testing and rating for performance Part 1: Water-to-air and brine-to-air heat pumps Part 2: Water-to-water and brine-to-water heat pumps	2021 2021
Europe	EN 378	Refrigerating systems and heat pumps - Safety and environmental requirements Part 1: Basic requirements, definitions, classification, selection criteria Part 2: Design, construction, testing, marking and documentation Part 3: Installation site and personal protection Part 4: Operation, maintenance, repair and recovery	2016 ⁵ 2016 ²⁶ 2016 ⁷ 2016 ⁸

¹ Amendments in 2015 and 2021

² Amendment in 2020

³ Amendment in 2021

⁴ new draft version in 2022

⁵ update A1 in 2020

⁶ draft update prA1 in 2019

⁷ update A1 in 2020

⁸ update A1 in 2019

Table B-3 – Standards and guidelines on heat pumps currently in force in Europe; there are more standards on individual components that are not listed here (continued on next page)

Country	Number	Title in English	Latest version	
Europe	EN 1861	Refrigerating systems and heat pumps - System flow diagrams and piping and instrument diagrams - Layout and symbols	1998	
	EN 13313	Refrigerating systems and heat pumps - Competence of personnel	2010	
	EN 14511	Air conditioners, liquid chilling packages and heat pumps for space heating and cooling and process chillers, with electrically driven compressors	Part 1: Terms and definitions	2018 ⁹
			Part 2: Test conditions	2018 ⁹
			Part 3: Test methods	2018 ⁹
Part 4: Requirements			2018 ⁹	
EN 14825	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	2018 ¹⁰		
DE	DIN 8930-2	Refrigerating systems and heat pumps - Terms and definitions – Part 2: General terms and definitions	2022	
	VDI 4645	Heating plants with heat pumps in single-family and multi-family houses - Planning, construction, operation	2018 ¹¹	
	VDI 4650	Calculation of the seasonal coefficient of performance of heat pumps	Part 1: Electric heat pumps for space heating and domestic hot water	2019
			Energy efficiency of electrically powered heat pumps - Coefficients of energy efficiency and their definition	2014

⁹ new drafts prEN 14511-1, -2, -3 and -4 in 2021

¹⁰ new draft prEN 14825 in 2020

¹¹ in addition, draft VDI-MT 4645-1 in 2022 on trainings, examinations, certifications of qualification for VDI 4645

Table B-3 (continued) – Standards and guidelines on heat pumps currently in force in Europe; there are more standards on individual components that are not listed here

Country	Number	Title in English	Latest version
World	ISO 18758	Mining and earth-moving machinery. Rock drill rigs and rock reinforcement rigs Part 1: Vocabulary Part 2: Safety requirements	2018 2018
	ISO/TR 14685	Geophysical logging of boreholes for hydrogeological purposes - Considerations and guidelines for making measurements	2001
Europe	EN 16228	Drilling and foundation equipment – Safety Part 1: Common requirements Part 2: Mobile drill rigs for civil and geotechnical engineering, quarrying and mining	2014 ¹ 2014 ²
DE	DVGW W 110	Well logging in open boreholes and wells for groundwater exploration and monitoring	2019
	DVGW W 115	Drilling for exploration, monitoring and production of groundwater	2008
	DVGW W 116	Application of drilling fluid additives for the construction of water and monitoring wells with flush drilling methods	2019
	DVGW W 118	Sizing of vertical filter wells	2005
	DVGW W 120	Qualification requirements for the sector of drilling technology Part 1: Well construction, regeneration, renovation and abandonment Part 2: Shallow geothermal (borehole heat exchangers)	2012 2013
	DVGW W 123	Construction and design of vertical filter wells	2001
	DVGW W 124	Supervision and completion during the construction of vertical filtering wells	1998
	DVGW W 135	Renovation and Abandonment of Wells, Monitoring-Wells and Boreholes	2018
UK	BS 7022	Guide for geophysical logging of boreholes for hydrogeological purposes	1989

¹ update A1 in 2021

¹ update A1 in 2021

Table B-4 – Standards and guidelines on well/BHE drilling and logging in force in Europe (other than for deep drilling for hydrocarbons etc.)

State	Title (German original title)	Topic(s) covered	Year of latest edition
Burgenland	Wärmepumpen ¹	GSHP general	2016
Kärnten (Carinthia)	Merkblatt Tiefsonden	BHE	2018
	Merkblatt Grundwasserwärmepumpe	GW wells	2018
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 bis 5 l/s ²	GW-wells	2006
Salzburg	Leitfaden Erdwärmesonden (Tiefsonden)	BHE	2017
	Leitfaden Grundwasser-Wärmepumpen	GW-wells	2017
Steiermark (Styria)	Strategiepapier Erdwärme 2.0 (Gewinnung von Erdwärme in Form von Vertikalkollektoren (Tiefsonden))	BHE	2022
Tirol (Tyrol)	Leitfaden zum Bau und Betrieb von Erdwärmesonden in Tirol	BHE	2016
Vorarlberg	On website only general text and templates for application ³	BHE, energy piles	-
Wien (Vienna)	Wärme!pumpen- Technologieleitfaden Wärmepumpen	All HP, incl. all SGE types	2014
	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.

³ a general brochure on GSHP existed: Nimm 4, zahl 1! Richtig heizen mit Erdwärme (2014)

Table B-5 – List of state guidelines for environmental evaluation and licensing of GSHP in Austria (status November 2022); some states also provide related maps, some online via GIS

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 horiz. 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	2019
Mecklenburg-Vorpommern	Erdwärmesonden und Erdwärmekollektoren in Mecklenburg-Vorpommern	BHE and horiz. loops	2015
Niedersachsen (Lower Saxony)	Leitfaden Erdwärmenutzung in Niedersachsen, rechtliche und technische Grundlagen für erdgekoppelte Wärmepumpenanlagen ³	BHE, horiz. loops, wells	2022
Nordrhein-Westfalen	Merkbl. 48, Wasserwirtschaftliche Anforderungen an die Nutzung von oberflächennaher Erdwärme ⁴	BHE, horiz. loops, wells	2004
Rheinland-Pfalz (Rhineland-Pal.)	Leitfaden zur Nutzung von oberflächennaher Geothermie mit Erdwärmesonden	BHE	2020
Saarland	On website only general text and template for application ⁵	BHE and horiz. loops	-
Sachsen (Saxony)	Erdwärmesonden, Informationsbroschüre zur Nutzung oberflächennaher Geothermie	BHE	2014
	Grundwasserwärmepumpen, Merkblatt zum Bau und Betrieb	Ground-water wells	2015
Sachsen-Anhalt	Erdwärmenutzung in Sachsen-Anhalt ⁶	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 2015

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

³ in addition a document from 2007 on design fundamentals for horizontal loops

⁴ probably no new edition to come, instead a web-based shallow geothermal site check (Standortcheck) is suggested (<https://www.geothermie.nrw.de/>); in addition a general brochure "Geothermie in Nordrhein-Westfalen erkunden · bewerten · nutzen" on all geothermal technologies from 2011 exists

⁵ a document "Leitfaden Erdwärmenutzung" from 2008 did exist, but is no longer available online.

⁶ in addition a document on quality control of BHE from 2016

Table B-6 – List of state guidelines for environmental evaluation and licensing of GSHP in Germany (status November 2022); some states also provide related maps, often online via GIS

Canton	Title (Original title)	Topic(s) covered	Year of latest edition
Aargau	Standortbeurteilung für die Nutzung von Erdwärme ¹	GSHP general	2017
Appenzell AR	Merkblatt Erdwärmesonden	BHE	2020
Appenzell IR	Merkblatt Erdsonden-Wärmepumpen	BHE	2021
Basel-Landschaft	Erdwärmenutzungskonzept BL, Wegleitung zur Nutzung der Erdwärme im Kanton Basel-Landschaft	GSHP general	2019
Basel-Stadt	Erdwärmesondenkarte Kanton Basel-Stadt ¹	BHE	2017
Bern	Allgemeine Bedingungen, Auflagen und Hinweise für die Erstellung und den Betrieb von Erdwärmesondenanlagen	BHE	2021
Fribourg	Karte der Zulässigkeit von Erdwärmesonden (EWS) - Merkblatt ¹	BHE	2021
Genève	online only, as fiches 8 and 9 of the dossier ‚Gestion durable des ressources du sous-sol‘ ²	BHE, wells	-
Glarus	Merkblatt Eingabeverfahren für die Wärme- / Kältenutzung von Grundwasser oder Erdwärme	BHE, wells	2018
Graubünden (Grisons)	Vollzugshilfe – Wärmepumpenanlagen, Anforderungen und Bewilligungspraxis	all HP	2022
Jura	online only, GéoPortail du Canton du Jura ³	BHE	-
Luzern (Lucerne)	Informationen zur Erdwärmenutzung ¹	BHE etc.	2022
Neuchâtel	Sondes géothermiques verticales	BHE	2009
Nidwalden	Nutzung der Erdwärme mit Erdsonden. Ablaufschema zu Bewilligungsverfahren ¹	BHE	2020
Obwalden	Merkblatt Planung, Erstellung, Abnahme und Betrieb von Wärmepumpenanlagen mit Erdsonden	BHE	2022
	Merkblatt Planung, Erstellung, Abnahme und Betrieb von Wärmepumpenanlagen mit Wärmequelle Grundwasser oder Oberflächenwasser	GW wells	2022
Schaffhausen	Bewilligung zur Nutzung der Erdwärme mittels Erdsonden, Erdkörben, Erdkollektoren: Allgemeine Auflagen und Bedingungen	BHE etc.	2021
Schwyz	online only, GeoPortal des Kantons Schwyz ⁴	all GSHP	-
Solothurn	Nutzung von Grundwasser und Erdwärme zum Heizen oder Kühlen ⁵	all GSHP	2014

¹ only valid in combination with GIS application

² <https://www.ge.ch/dossier/gestion-durable-ressources-du-sous-sol>

³ <https://geo.jura.ch/theme/Geologie>

⁴ <https://map.geo.sz.ch/>

⁵ In addition a short version on permitting, „Nutzung von Erdwärme zum Heizen oder Kühlen“ (2014)

Table B-7 – List of guidelines for environmental evaluation and licensing of GSHP in Swiss cantons (status November 2022); most cantons provide related maps, usually online via GIS (continued on next page)

Canton	Title (Original title)	Topic(s) covered	Year of latest edition
St Gallen	Infoblatt Gesuch für den Bau und Betrieb von Wärmepumpenanlagen mit Nutzung von Wasser oder Erdwärme ¹	all GSHP	2017
	Infoblatt Erläuterungen zur Erdwärmesondenkarte ¹	BHE	2020
Ticino	Linee guida per il rilascio di un permesso per lo sfruttamento dell'energia geotermica e della captazione di acqua sotterranea ad uso termico	all GSHP	2014
Thurgau	online only, ThurGIS ⁶	all GSHP	-
Uri	Wärmenutzungskonzept Kanton Uri	all GSHP	2017
Vaud	online only, Guichet cartographique cantonal ⁶	BHE, wells	-
Wallis / Valais	online only, Kantonales Geoportal ⁸	BHE, wells	-
Zug	online only, ZugMap ⁹	all GSHP	-
Zürich	Planungshilfe Energienutzung aus Untergrund und Grundwasser	All GSHP	2010
	Neues Bewilligungsverfahren für Erdwärmesonden-Wärmepumpenanlagen	BHE	2017

¹ only valid in combination with GIS application

⁶ <https://map.geo.tg.ch/>

⁷ <https://www.geo.vd.ch/>

⁸ https://sitonline.vs.ch/environnement/eso_admissibilite_SGV/de/

⁹ <https://www.zugmap.ch/>

Table B-7 (continued) – List of guidelines for environmental evaluation and licensing of GSHP in Swiss cantons (status November 2022); most cantons provide related maps, usually online via GIS

Type	BFE Document Number and Title
BHE	8617-de: Bewilligungsverfahren Erdwärmesonden in den Kantonen - Übersicht der Bewilligungsverfahren für Erdwärmesonden in den Kantonen
	8617-fr: Procédures d'autorisation pour les sondes géothermiques dans les cantons - Vue d'ensemble des procédures d'autorisation pour les sondes géothermiques dans les cantons
	8617-it: Procedure di autorizzazione nei diversi Cantoni per l'installazione i sonde geotermiche verticali - Panoramica delle procedure di autorizzazione per l'installazione di sonde geotermiche nei Cantoni
GW wells	8618-de: Bewilligungsverfahren Grundwasserwärmenutzung in den Kantonen - Übersicht über die Bewilligungsverfahren für Grundwasserwärmenutzungen in den Kantonen
	8618-fr: Procédures d'autorisation en matière d'utilisation de la chaleur des eaux souterraines dans les cantons - Vue d'ensemble des procédures en matière d'utilisation de la chaleur des eaux souterraines dans les cantons
	8618-it: Procedure di autorizzazione per l'utilizzo di calore dalle acque sotterranee nei Cantoni - Panoramica delle procedure di autorizzazione per l'utilizzo di calore dalle acque sotterranee nei Cantoni

Table B-8 – Different versions of the overview guides on cantonal permitting practice in Switzerland, BFE documents from 2017 (internal Nos. 8617/8618), available for download at: <https://www.bfe.admin.ch/bfe/en/home/supply/renewable-energy/geothermal-energy.html>

BFE Document No.	Title
BFE 9388-12-180613	<i>Erläuterungen «Mustersubmission für die Installation einer Erdwärmesonde»</i> [Explanatory notes on 'Application template for installation of one BHE']
BFE 9389-13-180613	<i>Erläuterungen «Mustersubmission für die Installation von 2-10 Erdwärmesonden am Beispiel einer Anlage mit 7 Erdwärmesonden»</i> [Explanatory notes on 'Application template for installation of 2-10 BHE, example for an installation of 7 BHE']
BFE 9387-11-180613	<i>Ergänzungen zu grossen Erdwärmesondenfeldern «Mustersubmission für die Installation einer Erdwärmesonde»</i> [Supplement on large BHE fields to 'Application example for installation of BHE']

Table B-9 – BFE documents from 2018 (internal Nos. 9387, 9388, 9389) for explanation of suggested BHE application templates (provided as MS-Word-files), available for download at:

<https://www.bfe.admin.ch/bfe/en/home/supply/renewable-energy/geothermal-energy.html>

Country (region)	Name of legislative document
Belgium (Flemish region)	<i>Besluit van de Vlaamse regering van 1 juni 1995 houdende algemene en sectorale bepalingen inzake milieuhygiëne (VLAREM II)</i> [Decision of the Flemish government of 1 st June 1995 containing general and sectoral regulations regarding environmental hygiene] relevant part is: <i>Hoofdstuk 5.55. Boringen</i> (Main Part 5.55. Drillings), and in particular: <i>Afdeling 5.55.2. Boringen in het kader van thermische energieopslag in boorgaten</i> [Section 5.55.2. Drillings in the field of thermal energy storage in boreholes] (latest version from 2017)
Germany (Hesse state)	<i>Anforderungen des Gewässerschutzes an Erdwärmesonden (Verordnung HMULV 21.03.2014)</i> [Water Protection Requirements for Borehole Heat Exchangers (Decree Hesse Minister for Environment etc., 21/03/2014)] (latest version from December 2021, Staatsanzeiger für das Land Hessen 2022 p16)
Italy	<i>Prescrizioni per la posa in opera degli impianti di produzione di calore da risorsa geotermica, destinata al riscaldamento e alla climatizzazione di edifici e misure di semplificazione per l'installazione dei predetti impianti (30-09-2022, Gazzetta Ufficiale Serie Generale n.241 del 14-10-2022)</i> [Decree on Requirements for the installation of heat production plants from geothermal resources, intended for heating and air conditioning of buildings and simplification for the installation of the aforesaid systems (30/09/2022, Official Gazette General Series no. 241 of 14/10/2022)]
The Netherlands	<i>Regeling van de Minister van Infrastructuur en Milieu, van xx augustus 2013, nr. IENM/BSK-2013/180443, tot wijziging van de Activiteitenregeling milieubeheer, de Regeling bodemkwaliteit, de Regeling lozen buiten inrichtingen, de Regeling omgevingsrecht en de Waterregeling (bodem-energiesystemen en BBT-informatiedocument)</i> [Regulation of the Minister for Infrastructure and Environment, ..., to amend the Activity Regulation on Environmental Administration, ... (ground energy systems and BAT information documents)] <i>Wijzigingsbesluit Activiteitenbesluit milieubeheer, enz. (regels inzake bodemenergiesystemen en enkele technische verbeteringen)</i> [Amendment Decision Activity Decision Environmental Administration, etc. (Rules regarding ground energy systems and some technical improvements)]

Table B-10 – Examples of national or regional/state legislation covering SGE