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GSHP DESIGN: GUIDELINES AND STANDARDS

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INTRODUCTION

For geothermal energy and heat pumps, three different areas have to be distinguished in the installation process, and they are typically covered by different workforces:

a) Installation on the geothermal side (drilling, pipe laying, well construction, etc.). No standards at EU level exist

b) Heat pumps (work with refrigerating/thermodynamic systems, systems under pressure, electrical safety, etc.). A number of standards exist at European or international level.

c) Classical heating and air conditioning installation (plumbing, radiators, air ductwork, etc.)

For the electrical side, IEC has developed a number of standards in the IEC 60335 series about safety of household and similar electrical appliances that are ratified on a European level. Item c) rules are identical for any conventional heating and cooling installation. The overall status of implementation of Standards across Europe is:

- Heat Pumps – there are comprehensive and harmonised technical standards for the equipment
- EU member states (such as Switzerland and Norway) have adopted the EN standards for testing, rating and safety of heat pumps
- EN Standards only exist for safety of drill rigs (shallow wells), and from the petroleum industry (which may have some relevance for any deep well drilling that might be carried out)
- For shallow geothermal systems, technical standards exist in the countries where the market is already well developed. This includes Germany, Sweden, Austria and Switzerland.
- Certification of installers and drillers only exists in those countries where the market has matured.

In the Geothermal and heat pump sector, standards and codes can be classified in various ways.

- Technical standards for efficiency, safety, longevity etc apply mainly for the heat pump sector
- Technical standards for environmental protection, as for drilling, borehole heat exchangers, etc. apply mainly for the ground side (geothermal)
- Regulations and guidelines for licensing of geothermal systems (typically concerning groundwater protection), include legal regulations for the access to and ownership of the geothermal resources
- Certification of skill and work quality for installers and drillers

The situation on Standards and certification is summarised below.

1 EUROPEAN STANDARDS

Heat pump equipment is covered by a comprehensive and well harmonised set of technical standards. Member states have adopted the basic EN standards for testing and rating, safety, etc. into national standardisation; Switzerland, Norway and Iceland have joined into the same set of standards. While not all relevant EN standards are yet implemented in all member states, the process is well under way.

In the same process, most pre-existing national standards have been withdrawn and replaced by EN standards. National standards existed in particular in the traditional heat pump countries like Austria, Germany, Sweden and Switzerland. In several cases, pre-existing national standards are kept valid for specific areas not covered by the EN standards.

For geothermal energy, EN standards only exist for the safety of drill rigs (shallow geothermal), and for the sector of the petroleum industry (which has some relevance for deep geothermal, together with US API standards). The standards from the petroleum industry are only listed in the common EN form, and their national adaptation is only apparent in Germany and France.

For shallow geothermal systems in general, technical standards exist in those countries where the market has already developed. This includes Germany, Sweden, Austria, and the non-member-state Switzerland. A similar situation also pertains for the certification/licensing of installers and drillers. Guidelines concerning the legal regulations for geothermal installations exist only in some countries with the most developed requirements being in some German states, and in some Swiss cantons.

Existing European Standards are listed below in table 1 for information of those involved in design of geothermal systems. The status of National Specifications (e.g. DIN, VDI) varies between countries. The content of these national Standards provide useful reference of local best practice and should be included as references for technical purposes.

Table 1: List of relevant standards on a European or international level (status 2011)

EN 378-1:2008	*Refrigerating systems and heat pumps – Safety and environmental requirements – Part 1: Basic requirements, definitions, classification and selection criteria* The 2008 revision included harmonisation with the European Pressure Equipment Directive (PED).
EN 255-3	*Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors - Heating mode - Testing and requirements for marking for domestic hot water units*
EN 14511-1:2004	*Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling – Parts 1-4*
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	*Water-source heat pumps -- Testing and rating for performance - Part 2: Water-to-water and brine-to-water heat pumps*
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*
EN 12170:2002	*Heating systems in buildings. Procedure for the preparation of documents for operation, maintenance and use. Heating systems requiring a trained operator*
EN 12828:2003	*Heating systems in buildings – Design for water based heating systems*
EN 12831:2003	*Heating systems in buildings - Method for calculation of the design heat load*
EN 15316/4/2:2008	*Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 4-2: Space heating generation systems, heat pump systems*
EN 15450:2007	*Heating systems in buildings. Design of heat pump heating systems*

The Normative Standard **“Heating systems in buildings – Design of heat pump heating systems”**, **EN15450** October 2007 concerns the design of heat pump systems not only for water and ground-source but for air-source as well. It is the first EN standard for the heat pump system in general. There are also a number of Standards on drilling which may be relevant to shallow geothermal systems.

EN 15450 elucidates the basic problem for a geothermal standard on a European level:

- Climatic conditions throughout Europe vary widely giving large differences in heating/ cooling demand;
- Geological conditions vary widely from unconsolidated soils to hard, crystalline rock;
- Traditions in heating and cooling vary significantly (e.g. hydraulic versus air-based systems, closed loop versus open loop).

As a result, it is recognised that EN 15450 can only give a general minimum framework for design and installation, with many items to be filled in locally or regionally. This standard contains the following sections:

1. System requirements;
2. Installation requirements;
3. Commissioning of the system;
4. Maintenance requirements.

According to this European Norm, the first appropriate parameter to be defined for the system design is the heat source which can be air, water or ground. Moreover, the electrical supply must be ensured as well as the positioning of the installation and its noise level. If an additional back-up heater is needed its power has to be reduced to a minimum since it is not a renewable energy technology. Furthermore, domestic hot water tank and other attached systems such as buffer storage must be specified. The control of the system, safety arrangements and operational requirements are of the utmost importance and must be defined according to the standards.

Concerning maintenance requirements for the system, there is reference to the EN 12170 and EN 12171. Moreover, it is mentioned that the staff involved in maintenance of the system must be qualified and certified according to EN 13313.

Finally there are four annexes which contain the following:

- Annex A (informative) – Guidelines for determining design parameters
- Annex B (normative) – Guideline for designing heat pump systems
- Annex C (normative) – Recommended minimum and target values for the SPF
- Annex D (normative) – Average daily tapping patterns for domestic hot water production.

2 NATIONAL STANDARDS

These national standards are listed in table 2 and are generally in the local language except VDI 4640 which is available in both German and English.

The most advanced and comprehensive national Standard is the **German document VDI 4640.** This German standard focuses especially on the GSHP system as a whole (mainly in part 2), in contrary to the others that focus more on discrete elements of the system. The contents of this document are as follows:

- Part 1: General / Licenses / Environment, status 2010-06
- Part 2: Ground Source Heat Pumps, status 2001-09, under revision
- Part 3: UTES, status 2001-06, under revision
- Part 4: Direct uses (cooling, ground-air heat exchanger), status 2004-09

Table 2: List of relevant standards on national level inside Europe (status 2011)

Country	Document Number	Document Title	Date
AT	ÖNORM M 7753	Heat pumps with electrically driven compressors for direct expansion, ground coupled	1995
AT	ÖNORM M 7755-2+3	Electrically driven heat pumps	2000
AT	ÖWAV Regelblatt 207	Thermal use of the groundwater and the underground, heating and cooling	2009
CH	AWP T1	Heating system with borehole heat exchangers	2007
CH	AWP T2	Heating system with horizontal ground collector, energy piles or energy cages	2007
CH	AWP T3	Groundwater as heat source	2007
CH	AWP T5	Filling of borehole heat exchanger systems	2007
CH	SIA D 0190	Use of earth heat through foundation piles and other building parts in contact with the ground	2005
CH	SIA 384/6 (SN 565)	Borehole heat exchangers for 2009 heating and cooling	2009
DE	DIN8901	Refrigerating systems and heat pumps – Protection of soil, ground and surface water	2002
DE	VDI 4640 Blatt 1	Thermal use of the underground – part1: Fundamentals, approvals, environmental aspects	2010
DE	VDI 4640 Blatt 2	Thermal use of the underground – part2: Ground source heat pumps	2001
DE	VDI 4640 Blatt 3	Thermal use of the underground – part3: Underground thermal energy storage	2001
DE	VDI 4640 Blatt 4	Thermal use of the underground – part4: Direct uses	2004
DE	DIN 8901	Refrigerating systems and heat pumps - Protection of soil, ground and surface water	2002
SE	Normbrunn-07	Drilling for water wells and energy	2008
* Note that Switzerland: AWP T1 is the first Standard to call for grouting to be carried out from bottom to top of the borehole installation.			

The first part of **VDI 4640** refers to the following general information for GSHP systems:

- Fundamentals concerning the definition of geothermal energy and the principles for the design of a GSHP system.
- Approvals concerning water rights as well as mining law.
- Safety aspects of the heat pumps.
- Location assessment concerning small systems up to 30kW depending on assumptions & estimates.
- Environmental aspects concerning the material selection for installations in the underground such as pipes, water mixture etc.

The second part of **VDI 4640** refers to design and installation of a complete GSHP system:

- Groundwater well systems (design and installation);
- Closed-loop systems:
  - horizontal loops - horizontal ground heat exchangers (design and installation)
  - vertical loops - borehole heat exchangers (design and installation)
- Special features of systems with direct evaporation (design and installation);
- Characteristics of other heat sources such as “energy piles”, compact horizontal ground heat exchangers etc;

- Incorporating the system (manifolds & collectors, fittings & pumps, connections pipes between manifolds and heat pumps, dimensioning the pipes and pumps);
- Heat usage systems;
- Dismantling GSHP systems.

The third part of **VDI 4640** refers to thermal energy storage, more specifically:

- General information of thermal energy storage (definitions, special environmental aspects, choice of materials for higher temperatures).
- Incorporation into an energy supply system (energy balance, temperature levels, utilization ratio of the storage system, uses: storage of cold and/or of low-temperature heat with or without a heat pump, solar energy and heat storage, heat and power cogeneration plant coupled with heat storage, complex energy supply systems utilizing and storing waste heat, further system variants of underground thermal energy storage).
- Aquifer storage (system description, natural site requirements, site exploration, design of the wells, special aspects relating to the licensing of aquifer storage, possible operating problems arising from the chemical composition of the groundwater).
- BHEs (geometry of the storage system, layout, construction).
- Other underground thermal storage (cavern storage, abandoned mines, near-natural underground thermal energy storage systems).

The fourth part of **VDI 4640** refers to thermal source systems without using a heat pump, more specifically:

- Direct thermal use of ground water (system description, environmental influence and special aspects relating to water management & water legislation, design).
- Direct thermal use of the underground with borehole heat exchangers, energy piles, etc. (system description, environmental aspects and questions relating to water legislation, construction and installation including dismantling).
- Air heating and cooling in the underground (system description, environmental aspects, air hygiene, design, installation, selection of materials, dismantling, control strategies, economic efficiency).

3 CERTIFICATION

The certification of drillers, installers etc and generally of all specialists that contribute to the design, installation and maintenance of GSHP systems is a very important issue in order to guarantee the proper operation of the system. Certified designers, manufacturers and installers (including drillers) are necessary to ensure high efficiency and longevity of a GSHP system. Also for the certification of drilling companies, joint basic rules should be developed in order to facilitate cross-border service.

For all parties involved in GSHP drilling and installation, only a few countries have existing schemes for licenses and certification for heat pumps or geothermal energy. Normally only the general rules for work and trade apply; these may in some instances act as trade barriers. It must be ensured that existing and upcoming special regulations will not prevent the exchange of work and services in the common market.

For the heat pump installation, the EU-CERT.HP program may prove very helpful, and has the potential for a common application throughout EU-27. National quality certificates such as in France are voluntary and may be included in a common scheme or may continue in co-existence without problems. No common activity exists yet for the ground side. For setting up such schemes, the co-operation of the relevant professional bodies and industrial associations will be necessary, in order to ensure acceptance of the resulting programs in the Geothermal sector.

Well drilling for water or shallow Geothermal used to be a regional business and so EU-wide rules have not been important. Some national certifications for drilling companies can develop into a barrier, if they are made mandatory by regional authorities. Relevant certifications from other member states need to be made acceptable to the authorities in other parts of Europe. Hence a common EN standard based on the national approaches should be initiated.

At present certification for drillers exists only in Germany, Sweden and Switzerland and in Austria this matter is under development. Table 3 gives an overview.

Table 2: List of relevant standards on national level inside Europe (status 2011)

DVGW W 120	Qualifikationsanforderungen für die Bereiche Bohrtechnik, Brunnenbau und Brunnenregenerierung	Certification of professional drilling companies	2005-12 (DE)
DACH-Gütesiegel EWS	Gütesiegel für Erdwärmesonden-Bohrfirmen	Certification of professional drilling companies	2001/2006 (CH/DE)
RAL/ZDB	RAL-Gütezeichen „Erdwärme“, Gütegemeinschaft Geothermische Anlagen	Certification of professional drilling companies	2007 (DE)
C-Borrare	Certifiering av brunnsborrningsföretag	Certification of well drilling companies	2006 (SE)

It is critically important that all site operations are carried out in a safe manner, without damage to the operators, the public or the environment. Safety requirements can be summarised by stating that respective national Standards, specifications or statutory requirements shall be applied wherever respective international Standards are not available (EN ISO 22475/1).

For quality testing and certification of heat pumps, the basic requirements are given by EN 14511 and, for the domestic hot water side, by EN 255-3. Other relevant heat pump standards like EN 378 or EN 60335- 2-40 (on electrical safety) are also common throughout Europe. Quality labels like P-mark in SE or the Gütesiegel Wärmepumpe in AT, DE and CH are based upon testing according to the common EN standards mentioned above. The European Heat Pump Association is working to establish a harmonised quality label (EHPA quality label), or at least to harmonise the existing ones.

4 LEGAL PERMITS

One of the commonest barriers to increased use of geothermal energy is the permitting process. Permits may be required for the use of groundwater as heat source, but also for BHE and for drilling as such.

Of course, regulations for permits are necessary in order to protect the groundwater and ground against pollution. A problem is more that the procedures and rationale for decision making vary greatly not just between member states, but also within countries on provincial level. In some case even the relevant permitting authority is unclear, as the example of water authorities and mining authorities for larger GSHP-plants in Germany shows. On the other hand, guidelines for permitting procedures and simplified procedures for small (residential) GSHP in non critical areas have facilitated the market growth in some German states and in CH.

The procedure of licensing of GSHP systems varies among European countries. In the field of permits for geothermal drilling and exploitation, European harmonisation could provide an outline framework with details to be completed at national or even regional level to accord with local provisions.

For example, German law governs shallow geothermal systems by water law but there are exceptions where shallow geothermal is governed by mining law. Moreover, the Federal Mining Act is applied at

a federal level and the Federal Water Household Act at a state level and so it is not obvious which is the relevant authority to address for each application.

Most German states have published own guidelines on how the application and licensing process should be handled. These publications actually guide the applicant to understand the procedure and point out the requirements for water protection. Good guidelines provide also an easy path for GSHP projects below a certain capacity, and in hydrogeologically unproblematic conditions.

In Austria, the permit for open and closed-loop GSHP systems is focused on water rights. A first guideline for application, like those of the German states, has been published in Upper Austria.

In Greece, given that there is a separate regulation for "systems for heating and cooling by the exploitation of the heat of underground and groundwater that are not considered as geothermal potential (temperature below 250C)", there is no confusion with the Mining Law. Moreover, there is no further reference to water rights and environmental issues.

According to these indicative cases, it is obvious that the main references to legal permits are water rights and the exploitation of underground potential.

5 CONCLUSIONS

The introduction of EN standards for heat pumps has been crucial as these products are manufactured and traded throughout Europe. Barriers for the trade of machinery and components hardly exist any more within the common market for heat pump systems. Efficiency or quality labels based on these standards are transparent and comparable among member states.

Some technical difference for ground-side installations (in particular BHE) and drilling between Scandinavian countries and Central Europe have their main reason in different geological situations, and thus cannot easily be harmonised. The Geothermal technology always has to respect the regional geological situation, which varies widely throughout Europe and cannot be influenced at all by policy.

Barriers for work and services do exist to some extent, but not more than in the construction sector in general. Specific certifications are voluntary, and new certifications for heat pump installers have the chance to become adopted in most of the countries.

The biggest problem is in the legal regulations, concerning both the environmental permits and the ownership / license for the resource. Without a clear title on the use of the resource, no investment is possible. However, this cannot be regulated by standards, but must be dealt with by the legislative bodies.

Because the drilling and installation for Geothermal systems in the shallow Geothermal realm typically is a service rendered by contractors more locally, the need for harmonised standards is not so urgent as the need for suitable standards at all, as in many countries no guidelines and standards exist and thus consumer protection is not guaranteed. Here a negative impact on the market can be expected if demand increases and poor workmanship is delivered in countries without specific standards.

Common Standards are therefore desirable for the Geothermal side. The first real standard under development in Germany and will deal with material, construction and installation of borehole heat exchangers.

Items to be covered in new European standards for shallow geothermal applications could include:

- Layout (sizing) of the geothermal system (groundwater wells, borehole heat exchangers, horizontal loops, etc.), in accordance to the different climatic and geological conditions within Europe

- Materials for wells, borehole heat exchangers, other pipe loops, manifolds, etc.
- Geothermal groundwater wells: Drilling, well construction and well completion
- Borehole heat exchangers: Drilling, installation and completion (grouting, or open completion)
- Pipe laying for horizontal loops
- Other types of ground heat exchangers
- Connection to heat pump or other systems, system integration, interfaces

Considering the large differences in climate and geology, standards with a generic framework for Europe and appendices specific to countries (or regions) might be an option.

Generally, certification of specialists and GSHP system components will guarantee the quality and proper operation of GSHP systems and it will help the European market to have a rapid growth.

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