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Geoenergy permit practices in Finnish municipalities – Challenges with good governance

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ABSTRACT

The rapidly increasing renewable energy installations are often controlled through permit schemes, and good permit practices need to be developed for energy policy planning purposes. In Finland ground heat exchangers (GHEs) for geoenergy systems commonly need a permit from the municipal building control. We examine this municipal permit scheme, its functionality in groundwater protection and compatibility with the principles of good governance. Our data consists of permit and notification documents, interviews of building control officials and municipal regulations and instructions from nine municipalities in Southwest Finland. Similar studies based on empirical data have not been conducted earlier on geoenergy permit schemes. Despite common legislation there were many differences between municipalities in the application-stage permit practices, municipal regulations, supervision and quality control of GHEs. Well-functioning permit practices safeguard both the public and the neighbors' interests, promote groundwater protection and support the client with quality control.

1. Introduction

Energy policies in many countries are being tuned up to promote renewable energies inspired by the IPCC's Special Report on Global Warming of 1.5 °C [1]. In many parts of the world geoenergy, as an established energy technology, is in a good position in the redistribution of the energy market. For instance, in Finland, since 2013 more than 50% of new detached houses have had a geoenergy system installed [2]. In the Nordic countries, including Finland, the term geoenergy refers to shallow geothermal energy (SGE) that consists of the Earth's heat flux and stored solar energy.

While energy policies generally aim at increasing the use of renewable energies, the policy targets simultaneously need to take into consideration other formal goals and informal interests. Formal goals include the tangible environmental requirements (in the case of geoenergy systems often related to groundwater protection) and good governance, or the ways how decisions concerning resource management are implemented [3]. On the other hand, the rather delicate balance between private rights and public interest has to be taken into account: to what extent and in what circumstances can the latter prevail over the former? The interests of different stakeholders need to be balanced to achieve equality and justice. These questions are central in the widely applied permit schemes that allow monitoring and regulating renewable energy installations.

For this reason, identifying and incorporating good permit practices is crucial when developing permit schemes for renewable energies. The Council of Europe has issued the 12 Principles of Good Governance [4], which should also apply to permit procedures related to geoenergy. According to the principles, any permit scheme should follow the national rules and regulations, and decision-making should be transparent and treat all applicants of permits equally (Principles 4 and 5). All public services should be delivered within a reasonable timeframe, and procedures should be adapted to the legitimate expectations and needs of citizens (Principle 2). Moreover, the professional skills of those who deliver governance should be continuously maintained and strengthened in order to improve their output and impact. (Principle 7).

The rapidly growing numbers of geoenergy systems installed in Finland have highlighted the need to monitor and supervise where and how ground heat exchangers (GHEs) are installed. In the case of geoenergy and GHEs, possible benefits of permit schemes include avoidance of problems for adjoining properties, possibility of including building specifications in the permit regulations, protection of groundwaters, and registering locations of new GHEs in each municipality [5].

The Finnish land use and building legislation amendment in May 2011 introduced a permit scheme that applies generally to all new GHEs.

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Nomenclature

AVI	Regional State Administrative Agency (Aluehallintovirasto)
BHE	borehole heat exchanger
ELY Centre	Centre for Economic Development, Transport and the Environment (Elinkeino-, liikenne- ja ympäristökeskus)
GHE	ground heat exchanger
GIS	geographic information system
GSHP	ground source heat pump
SGE	shallow geothermal energy
SPF	seasonal performance factor

In addition to the duties and regulations that follow from the permit scheme, section 119 of the Finnish Land Use and Building Act [6] directly assigns a duty to take care in building activities to the party engaging in a building project, i.e. the client: "*A party engaging in a building project shall ensure that the building is designed and constructed in accordance with building provisions and regulations and the permit* granted." In addition to the above-mentioned building permit scheme, there is a parallel permit scheme that is applied to GHEs in the vicinity of groundwater reserves (Table 1).

In Finland, the municipalities traditionally have a high degree of autonomy, which is also acknowledged in Finland's constitution [10]. This enables rather great differences among municipalities in the practical procedures as far as the general principles of good governance (see above) are respected. In principle, each municipality is responsible for land use planning, building control, and environmental protection within its borders. At the same time, the regulations applied should as far as possible respect the landowners' private right to make their own energy choices.

1.1. Geoenergy permit schemes and governance – the state of the art

Earlier studies and reports have discussed the divergent permit practices in Finnish municipalities regarding small-scale renewable energy generation in general [11–13], and geoenergy practitioners' views on the permit procedure in particular [5]. They have recommended for example simplifying, speeding up and harmonizing the permit processes with nationally standardized procedures, and developing training and instructions for building control officials regarding the construction of geoenergy systems.

Geoenergy permit schemes and their possible development needs have also been examined in several other countries. Bleicher and Gross [14] studied topics related to geoenergy permits in Germany. Based on expert interviews, they defined two different modes to describe the ways in which environmental officials may handle permit applications: Officials adopting the *expert mode* do not rely on some standard set of criteria in their decision making. Instead, they adapt and combine aspects from different guidelines, taking account of new findings and particularities of each case. The expert mode is typically adopted by officials who have geological, hydrological or appropriate technical expertise. The opposite approach, the *administrative mode*, means that permit decisions are made based on standard guidelines provided by for example an expert working group at the federal state level.

Hähnlein et al. discussed the international legal status [15] and the environmental, technical and social sustainability of shallow geothermal energy (SGE) use [16]. In the latter study, they suggested a legal framework for the sustainable use of SGE. The framework was a workflow for the preparation of permit decisions in geoenergy projects. The workflow proceeds through classification, technical assessment and environmental assessment, leading to a licensing decision.

Tsagarakis et al. [17] investigated SGE legislation in 13 European Union member states and Turkey. To harmonize the highly diverse administrative procedures and requirements among the EU member states, they called for the EU to develop legislation and standards on geoenergy. Somogyi et al. [18] reached similar conclusions in their review article that discussed the regulation of shallow geothermal systems in six European countries. They highlighted the importance of up-to-date scientific research in formulating a transnational legislative framework.

Also, Garcia-Gil et al. [19] encouraged the development of proper policy and legal frameworks for SGE use. They proposed a comprehensive management structure and governance model for SGE resources that would incorporate for example thermally and environmentally sustainable use of SGE resources. In SGE projects thermal interference is a potential source of conflict between stakeholders, and Garcia-Gil et al. suggested that co-management of SGE resources should be developed to reduce conflicts. To promote environmental sustainability, they listed precautionary measures such as regulations on heat carrier fluid type, tests on refrigerant tubing, and evaluation and risk assessment during the licensing procedure.

Karytsas and Chaldezos [20] reviewed the legislative framework for GSHPs in Greece, where a Ministerial Decree controls the terms, conditions, documentation and procedures for licensing GSHP systems. They suggested simplifications to the licensing procedure for closed loop GSHP systems and implementing a certification scheme for GSHP contractors and drillers.

In an article published in 2015, Liu et al. [21] compared the status of GSHP applications in the United States and China. Their study covered for example GSHP policies and incentives, standards and certifications. In the United States, professional licenses or certifications were commonly required from GSHP system designers and installers already at that time, while in China certification systems had not been developed specifically for GSHP professionals.

Table 1
Permit schemes for ground heat exchangers in Finland.

	Action/building permit	Water permit
Legislation	Land Use and Building Act, section 126a [6]	Water Act, chapter 3, section 2 [7] Environmental Protection Act, section 17 [8]
Competent authority	Municipal building control	Regional State Administrative Agency (AVI, Aluehallintovirasto)
Aim of legislation in relation to GHEs	Control installation of GHEs as for their potential impacts on natural conditions and surrounding land use	Groundwater protection
Application of legislation	In most municipalities new GHEs need (a) an action permit (simplified building permit procedure for retrofit projects) or (b) a building permit (GHE is approved as part of a larger construction project). A municipality may decide that permits are not needed, and thus (c) a notification procedure is usually applied.	Applied when a planned GHE is located on a designated groundwater area[a]. The municipal authority may request a statement on the need of a permit from the Centre for Economic Development, Transport and the Environment (ELY Centre).

[a] Designated groundwater area refers in this article to those aquifers that have received a legal status based on the fact that they were classified suitable for drinking water extraction by the ELY Centres [9].

Jardeby et al. [22] reviewed the legislation and permit procedures for SGE systems in Sweden. A notification procedure is generally applied to geoenergy projects, and municipalities may also apply a permit procedure if that is necessary to protect human health and the environment. Guidelines for drilling water wells and BHEs have been published in the Normbrunn handbook [23], and a certification scheme is available for drillers in Sweden. According to Jardeby et al. neither of these are mandatory by national legislation but municipalities may require following the guidelines or using a certified driller.

Park et al. [24] conducted a survey among local planning authorities on the planning process for micro-wind turbines in the UK. They found considerable variation in the guidance and implementation of planning procedures across the UK and called for further research to develop the siting guidance for micro-wind turbines.

1.2. Research questions

The above reviewed geoenergy literature has dealt extensively with the legislation and its implications for the geoenergy industry and for the relevant permit and license procedures in different countries. Our article goes behind the legislation and examines the permit processes at the municipal level, where the building control departments apply the legislation into practice. This approach has not been applied to geoenergy permit schemes earlier, but some parallels can be found in the article on micro-wind turbine planning processes by Park et al. [24].

This study examines the GHE permit schemes and their functionality at the local level in Finland from the environmental management, institutional and governance perspective. It was designed to investigate the following questions:

(1) How do permit processes differ between municipalities?
(2) How do the current permit schemes in Finland fulfil the criteria of good governance as defined by the Council of Europe?
(3) How do current permit procedures meet the needs of different stakeholders?
(4) How often, and in what circumstances, are permits rejected due to environmental causes?

This study is a part of a project that investigates the policies, regulation, environmental and technical challenges, and permit procedures related to geoenergy systems in Finland [5,25,26]. The aim of the project is to find out and propose solutions to issues that may cause conflicts between different stakeholders in geoenergy projects. These stakeholders include (potential) owners of geoenergy systems, neighbors, geoenergy practitioners, the public administration and, notably, the environment.

2. Technologies for geoenergy utilization

Practically all geoenergy systems in Finland consist of a ground source heat pump (GSHP) connected to a closed loop ground heat exchanger (GHE) as the heat source. Hydronic heat distribution delivers the heat from the GSHP to the building, in most cases through underfloor heating or wall-mounted radiators. Open-loop groundwater heat pump systems are very rare in Finland although their applicability has been demonstrated [25,27].

A GHE is a plastic pipe loop filled with heat transfer fluid that in Finland is usually an ethanol solution. Other types of heat transfer fluids such as propylene glycol, ethylene glycol and potassium formate are rarely used, although they are widely used for example in Central Europe [25,28–30]. Earth-air-heat exchangers, or air-ground heat exchangers [cf. 31–34 are not used in Finland.

In order of frequency, the applied GHE types in Finland are [25].

1) Borehole heat exchangers (BHEs): most commonly a single U-shaped plastic pipe in a borehole in the bedrock, typically reaching a depth of 100–250 m;
2) Horizontal ground heat exchangers: a plastic pipe loop in the ground at a depth of 1.0–1.5 m;
3) Surface water heat exchangers: a plastic pipe loop at the bottom of a lake, pond, or sea at a minimum depth of 2 m.

The practical framework for geoenergy utilization and permit processing in Finland is defined by the geology of the Fennoscandian shield stretching from northwestern Russia and Finland to Sweden and Norway. It is characterized by hard, crystalline bedrock, and scarcity of sedimentary rocks [35]. Thus, the construction methods for BHEs differ in certain ways from those applied in areas dominated by sedimentary rocks. For example, methods like cable tool drilling or conventional rotary drilling are not efficient enough in the hard bedrock, and therefore down-the-hole drilling is the only method used for drilling BHE boreholes in Finland [36] p. 180]. Also, boreholes are generally not required to be backfilled, as they are not very prone to subsidence, and the groundwater table is commonly within 10 m from the ground surface. On the other hand, other methods are to be applied to prevent ingress of surface water into the boreholes [25].

The most common challenges and risks with GHEs in Finland relate to groundwater quality (heat transfer fluid leaks, hydraulic connection of superposed aquifers, contamination by surface water), changes in the level of groundwater, and artesian aquifers [25]. On the other hand, the Finnish geology is relatively safe to drill since it does not involve high risks such as subsidence-prone karst or swelling anhydride formations that have been behind some serious damage events in central Europe. Furthermore, the pressure in Finnish artesian bedrock aquifers is generally not very high and thus rarely causes major problems [25,37].

As Rybach and Sanner [38] anticipated, by 2020 the seasonal performance factors (SPFs) of advanced models of vapor compression GSHPs approach or exceed 5 in new buildings also in northern Europe. SPF refers to the efficiency of the heat pump and is calculated as the heat energy produced divided by the electric energy consumed. This development makes GSHPs an increasingly attractive method for power-to-heat conversion and thus variable renewable energy integration and decarbonization [39,40].

3. Materials and methods

The material for this study were collected from nine municipalities in Southwest Finland. The material consisted of (1) permit application and decision documents, and notification documents regarding GHE systems, (2) personal interview surveys with building control officials who deal with GHE permits in each municipality, and (3) related literary documents available in each municipality. The documents of more than 500 permit applications and notifications were analyzed. The advantage of using multiple types of data was that it provided a broader picture of the permit practices.

3.1. The study design

The province of Southwest Finland (*Varsinais-Suomi*) comprises 27 municipalities and had approximately 475 500 inhabitants at the end of 2016 [41]. For the purposes of this study, the municipalities were divided into three groups according to their population size: small municipalities (less than 5000 inhabitants; 10 municipalities), medium-sized municipalities (5000–15000 inhabitants; 8 municipalities), and large municipalities (more than 15000 inhabitants; 9 municipalities). This enabled sampling municipalities with different sized administrations and varying degrees of urbanization (see *% of population living in population centers*, Table 2). Initially twelve municipalities were randomly sampled for this study, four from each size group. One of the selected small municipalities notified that they were not able to provide

Table 2
The study municipalities: basic statistics and interview details.

Municipality	Population at end of 2016 [42]	% of population living in population center(s) [42]	Land area km^2 [43]	Interviewee (date of interview)
Salo	53546	74.9	1986	Inspection engineer (3 Jan 2018)
Kaarina	32738	94.7	150	HPAC inspector (28 Nov 2017)
Lieto	19418	82.9	300	Building inspector (22 Nov 2017)
Somero	9027	56.8	668	Building inspector (3 Oct 2017)
Laitila	8520	69.4	532	Building inspector (17 May 2017)
Mynämäki	7842	65.5	520	Building inspector (29 Nov 2017)
Aura	3984	69.6	95	Building inspector (11 Oct 2017)
Pyhäranta	2075	42.3	143	Building inspector (1 Sep 2017)
Oripää	1363	51.2	118	Technical manager (11 Oct 2017)

the requested data because of their clients' privacy protection policy. (Such privacy is not required by Finnish law.) One of the middle-sized municipalities did not respond to the data requests after repeated attempts (for large municipalities, see below).

Concerning the small and medium-sized municipalities, all available permit applications and decisions, and notifications were studied from May 2011, i.e. the onset of the permit scheme, until the end of 2016. During inquiries, it became clear that the total number of permit applications in the large municipalities alone would be in the order of 1000–1500. Thus, in relation to the large municipalities, we decided to concentrate on applications of the year 2014. This year was chosen because in that particular year, the numbers of geoenergy applications peaked in the small and medium-sized municipalities. Furthermore, the large municipalities were randomly ordered, and data collection halted after the cumulative number of applications from all large municipalities combined exceeded 200. Thus, one of the large municipalities was left out, and in the end, nine municipalities provided the data for this study (Table 2). The municipalities were randomly assigned the codes Large 1 (L1), Medium 1 (M1), Small 1 (S1) etc., which are used in the following sections.

For each permit application or GHE notification the following data were collected:

- application's date of arrival, date of decision, and date of decision issue
- objective of application: for an action permit, or for a building permit
- type of GHE installation: a BHE, horizontal GHE or a surface water heat exchanger; the number of loops
- permit decision, possible reasons (for rejection), and permit regulations
- decision maker: inspector's name, or building board

The permit practices were studied by a personal interview survey [44] with municipal building control officials. The interview survey outline is enclosed as an Appendix. One interviewee was contacted in each municipality. The questions were discussed with the interviewees and their responses were directly typed on the computer. The interview survey consisted of open-ended questions on:

- the application processes and practices
- preconditions for GHEs
- quality control and permit regulations for GHEs
- environmental impacts of GHEs
- instructions and training the officials had received relating to geoenergy permits.

Literary documents relating to GHEs, if available, were also analyzed for each municipality. These included:

- municipal environmental protection regulations and building codes: possible notes on GHEs
- GHE permit application instructions and GHE instructions: availability of written instructions and their contents

The applied methodology is illustrated in Fig. 1. The interview survey data, permit documents and municipal regulations and instructions were analyzed using qualitative content analysis [45–47]. The collected data was first organized according to topics, and after a preliminary identification of themes, relevant parts of the data were assembled into tables according to the topics of interest (i.e. subheadings in the Results section). Themes were further identified within these tables, and the municipalities' approaches to each topic were compared. In the synthesis we analyzed how the permit practices comply with the principles of good governance, how well the permit procedures meet the needs of different stakeholders, and which of the applied permit practices could be recommended.

3.2. Application statistics

The documents of 419 permit applications and 86 notifications from the period 2011–2016 were analyzed for this study (Fig. 2). 311 applications concerned an action permit (retrofit geoenergy installations), and 108 applications concerned a building permit (geoenergy installations in new buildings or in connection with a larger renovation).

4. Results

This section describes first the application-stage permit practices in the studied municipalities; second, the role of municipal regulations in the permit process; third, the contribution of building control officials to permit supervision and quality control of geoenergy systems; and fourth, observed environmental impacts of geoenergy systems and causes of permit rejections in the municipalities.

4.1. Application-stage permit practices

In this section we describe the procedures (permit vs. notification) applied to GHEs in each municipality; the application process and documents required with applications or notifications; handling fees for GHE permits or notifications; handling times of applications; and the instructions applied in the permit process in each municipality.

A summary of application-stage permit practices in the studied municipalities is presented in Table 3. In relation to new building projects, the building inspectors of seven municipalities mentioned that permits for GHEs were included in the building permits. In one large municipality separate action permit decisions for GHEs were made also in these cases. For retrofit projects, a permit procedure was clearly more popular and only two municipalities had imposed a notification procedure in their building codes (Table 3).

A site plan, illustrating the location of the GHE, was always required as an attachment to the application or notification. While some municipalities required an attachment to the application describing the construction methods of the GHE (Table 3), some others only required that

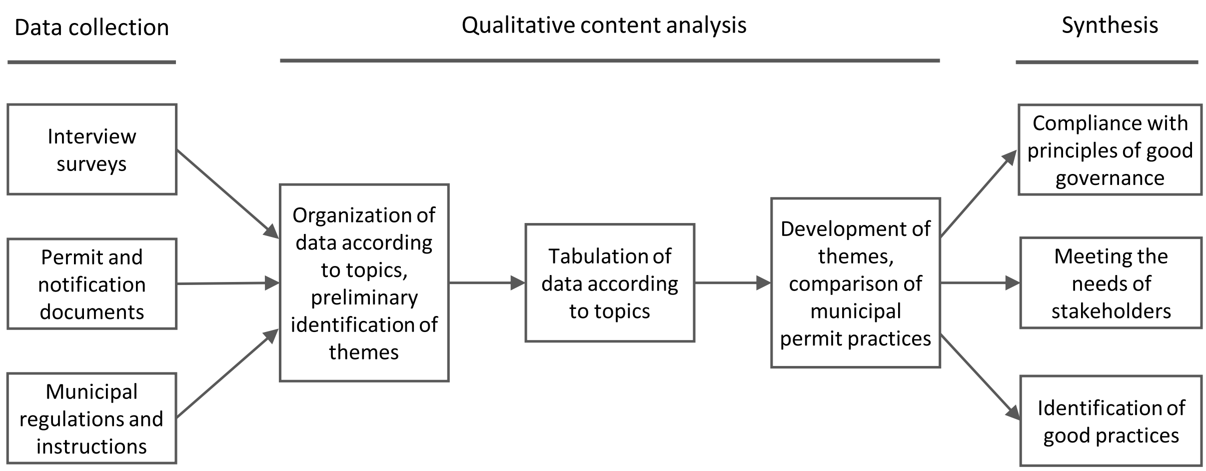

Fig. 1. A flow chart of the methodology applied in this article.

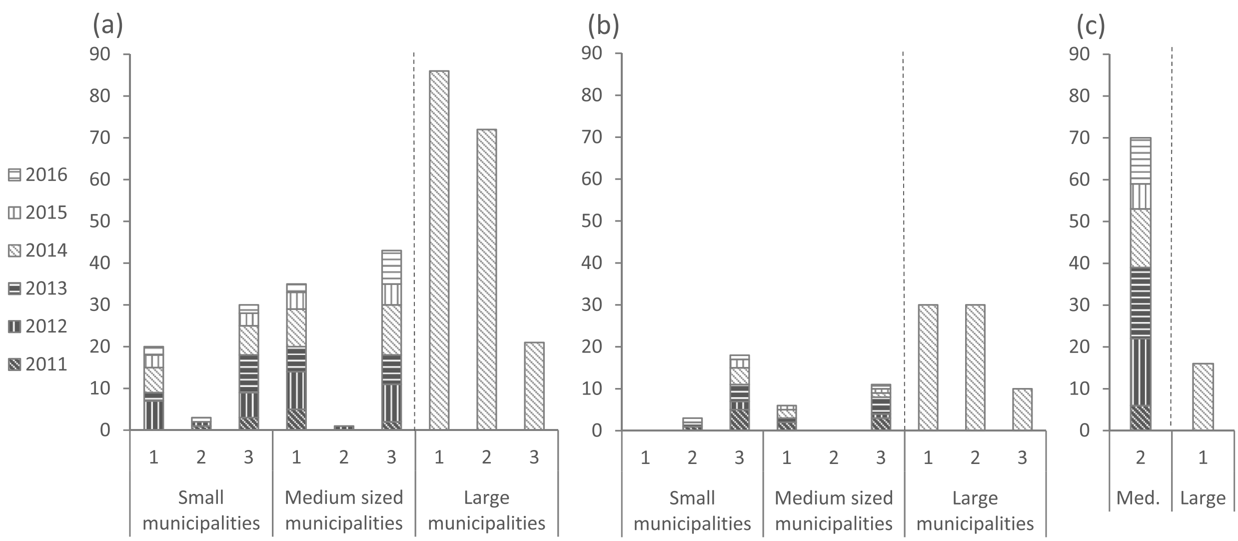

Fig. 2. Temporal distribution of the analyzed GHE applications and notifications in the nine municipalities. (a) Action permit applications, (b) applications for a building permit including GHE installation, and (c) GHE notifications. Note that in the large municipalities data were only collected for the year 2014.

Table 3
Application-stage permit practices for GHEs in the studied municipalities. In addition to the documents required with application shown in the table, a certificate of possession is automatically required by law, and this was explicitly listed as a requirement by four municipalities.

		L1	L2	L3	M1	M2	M3	S1	S2	S3
Procedure for retrofit GHEs	Permit	+[a]	++	++	++		++	++	++	++
	Notification	+[a]				++[b]				
Documents required with application or notification	Site plan	++	++	++	++	++	++	++	++	++
	Construction method description			++			+			++
	Neighbor hearing	+[c]	+[c]	+[c]		+[c]		+[c]		++
	BHE siting survey	+[d]						+[d]		
Application process (by Jan 1, 2018)	Electronic[e]	+	+			+		+	+	+
	Printed			++	++		++			
	Online information available		+	+		+		+	+	

++ Always; + In some cases.
[a] Permit inside town plan zones and designated groundwater areas, otherwise notification.
[b] Notification procedure officially adopted in 2012.
[c] Hearings if distance between GHE and property border, neighbor's well etc. is below a defined limit.
[d] Applied to large projects.
[e] Primarily an electronic application process but also printed applications accepted.

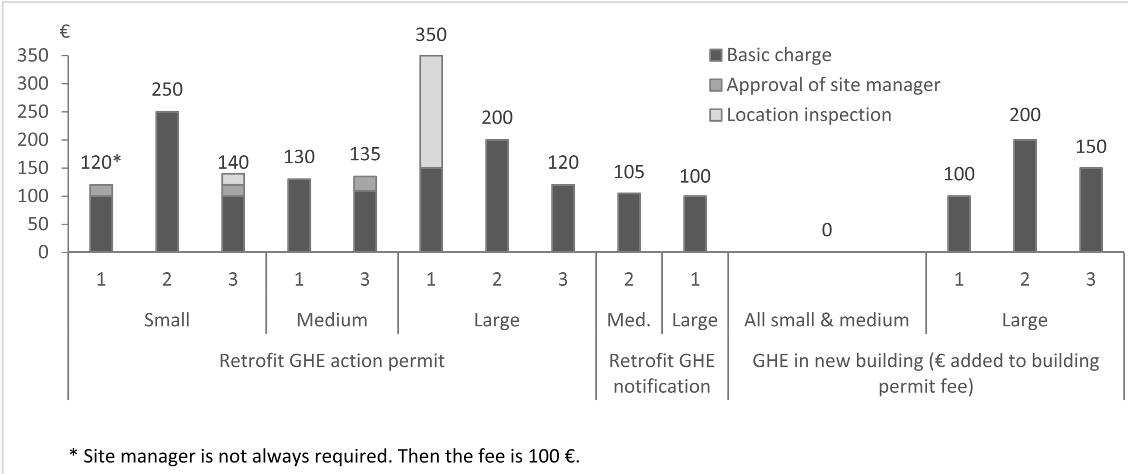

Fig. 3. The handling fees of GHE permits and notifications in the studied municipalities. These include all fees charged in connection with a GHE project, i.e. the permit and possible additional fees for inspections and approval of a site manager.

for example the BHE's depth and possible inclination were marked on the site plan.

Regarding distances between BHEs and property borders, the municipalities had varying practices. Most municipalities required neighbor hearings (or in some cases neighbor's consent) if the distance between the BHE and property border is less than a defined limit (Table 3). However, this limit varied greatly, from 4 to 50 m. Several municipalities applied a limit of either 7.5 or 10 m.

By the beginning of 2018, six municipalities had introduced an electronic application system (Table 3). Apart from that, in most municipalities there had not been major changes in the permit processes since the enactment of the permit legislation in May 2011. However, in one small municipality the permit administration had been transferred to the building control in the neighboring municipality since the beginning of 2017. In another small municipality the permit process had become more detailed due to introduction of new forms.

Handling fees for permits and notifications varied between 100 and 350 € in the studied municipalities (Fig. 3). In some municipalities there was a single basic charge that covered all costs, while in others an extra charge was added for the approval of a site manager, or for the location inspection.

The handling times of 296 GHE action permit applications were calculated. The average handling times for different years are shown in Fig. 4. The dates of arrival were not available in all application documents (all applications in one municipality and some in the other municipalities); these cases were omitted from the analysis. 78% of the annual averages calculated for Fig. 4 were below three weeks, while 11% were over five weeks. The handling times of individual applications varied between 1 and 86 days. Altogether 22 applications (7%) took more than five weeks to process, and the share of these varied from 3% to 36% depending on the municipality.

In principle, GHE notifications must always be handled within two weeks from their arrival to the building control: within two weeks the building inspector notifies the client if further clarifications or a permit application are required; if not, the project is allowed to proceed to implementation.

Regarding instructions they had received for handling GHE permits, three interviewees mentioned the Energywell handbook published by the Finnish Ministry of the Environment [48]. All the interviewees were asked for improvements to the Energywell handbook, whereupon they mentioned for example instructions on how to prevent and handle problematic situations and special cases, and more detailed instructions for new inspectors.

In relation to instructions for handling GHE permits, three interviewees mentioned courses and training days offered by the Finnish Society of Building Inspectors. Two interviewees had actually attended such a course. One interviewee mentioned the municipality's own instructions for GHE systems, which serve as a guideline for the inspectors. One interviewee pondered that "It probably wouldn't hurt to get some more information".

4.2. Municipal regulations

Municipal environmental protection regulations may be relevant for the permit process, and municipalities also give case-specific permit regulations with the permit decisions.

Municipal environmental protection regulations may be given based on section 202 of the Environmental Protection Act [8], which states that "*To enforce this Act, municipalities may issue necessary general regulations based on local circumstances*". In the five municipalities that had revised their environmental protection regulations after mid-2011, GHE systems were considered regarding either GHEs on designated groundwater areas, composition and handling of heat transfer fluids, or the distance between BHEs and sewage treatment (Table 4).

Six municipalities had an established procedure for GHEs on designated groundwater areas (Table 4). The interviewed inspectors did not know any cases in which the client would have applied for a permit to build a GHE on a designated groundwater area from the regional administration (AVI). Three of them mentioned that clients generally drop their projects when they realize that such a permit might be needed because they consider the application process too laborious. Also,

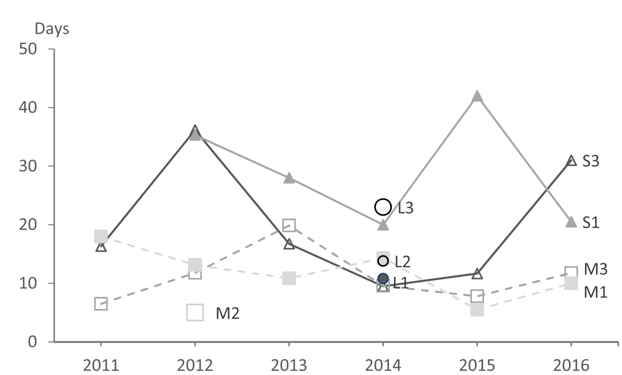

Fig. 4. Average handling times in different years (from date of arrival to date of decision issue) of applications for an action permit in the studied municipalities.

Table 4
Specific municipal regulations on the geoenergy systems.

		L1	L2	L3	M1	M2	M3	S1	S2	S3
Municipal environmental protection regulations	Consider GHEs	+	+	+	+					+
	HTF quality and recovery after use	+		+						
	HTF quality on DGAs		+		+					
	Handling of drill cuttings and sludge[a]	+		+						
Established procedure for GHEs on DGAs[b]		+	+	+	+	+			+	

HTF – heat transfer fluid; DGA – designated groundwater area.
[a] One municipality regulated this in environmental protection regulations, the other in permit regulations.
[b] Permit from AVI, statement from ELY Centre, and/or approval by municipal environmental authority required.

liability for damages in case of groundwater contamination was mentioned as a deterrent. One interviewee even pondered: "I guess I have scared them so effectively." Another interviewee mentioned that his municipality applies the procedure described in Table 1, and if the statement by ELY is negative, the clients in practice drop the project. However, if the statement is positive, they may file an application to the AVI.

Permit regulations are defined by section 141 of the Land Use and Building Act [6]: "*Whatever regulations are necessary may be included in the permit decision. Regulations may concern, among other things, how construction work is carried out or action taken, and the limitation of any harm that may be caused by them.*" These regulations are legally binding, unlike the permit instructions that some municipalities have constructed to guide the applicants. However, although the permit instructions are non-binding as such, building inspectors may use them as a guideline, and thus incorporate them in the permit regulations.

The amount of permit regulations varied between municipalities. Some municipalities included no regulations into the permits while others listed several relating to for example the location of GHEs, technical details and environmental safety. One interviewee told that he wanted to go through all the details with the clients beforehand, and usually did not write anything specific into the regulations since "the clients may not read the permit regulations so well".

In several municipalities permit instructions or regulations (only the latter being legally binding) defined minimum distances (or recommendations) to other BHEs, water wells, buildings, property borders, sewage treatment and pipes, water and heating pipes, and tunnels. These distances were commonly in line with the Energywell handbook [48 p. 25].

Permit regulations sometimes reminded that before drilling and excavation work, underground pipes and cables must be pinpointed and secured, or that the client and the drilling contractor must survey the prerequisites and risks of drilling beforehand. Also, technical details were sometimes defined in permit regulations, for example that the borehole lid must be marked visibly if covered with soil, or that in some cases borehole lids must be able to support traffic load.

In Finland geoenergy systems are commonly retrofitted in place of old oil-fired boilers. The permit regulations (and instructions) in one large municipality stated that before the installation of a BHE, (underground) oil tanks to be taken out of use must be cleaned and removed, and the ground must be inspected to detect possible oil leaks. Plans for this must be presented in advance to the municipal environmental authority. Sometimes permit regulations contained instructions in case asbestos had been used in the old plumbing.

In some municipalities, the permit regulations informed clients about the contents of legislation by defining assignment and limitations of liabilities. The permit regulations in one large municipality stated that the licensing authority is not responsible for possible groundwater changes. In two large municipalities, the permit regulations required the client to personally ensure that laws, orders, regulations, and permit regulations were observed, and that the construction work was sufficiently supervised and inspected.

4.3. Supervision and quality control

To conform with the principles of good governance, the permit practices should support the clients during the design and construction of a geoenergy system. In most municipalities the clients commonly sought personal guidance with the building control to clarify the permit procedure before application submission. This consulting was usually done by phone or e-mail, but one interviewee mentioned that he also visited most building sites at this stage to check the location of and required safety distances around the GHE.

Some municipalities handled the quality control of geoenergy installations by requiring that a site manager, i.e. a responsible foreperson to direct the work, was nominated (Table 5). However, the effectiveness of this measure was limited because most municipalities had not specified any competence requirements for the site manager, and thus for example the clients themselves could act as site managers.

In terms of quality control, some building inspectors controlled certain details at inspections, such as pipe connections, floor drains, pipe insulations, and whether the client had received user guidance. On the other hand, in two municipalities the final inspection was based on written documents so that the inspectors never actually visited the sites

Table 5
Quality control of geoenergy installations in the permit procedures of the studied municipalities.

		L1	L2	L3	M1	M2	M3	S1	S2	S3
Site manager required		++	+	++	+		++	+		++
Final inspection by municipality	On site		++	++			++	++		++
	Only based on documents	++			++					
Documents required after completion	Drilling log	++	++	++	++		++			++
	Installation report[a]	+[b]	++	++			++			++
GHE to map or GIS	GHE location verified	+[c]	++	++	++					
	At property level					++	+[d]	++		

++ Always; + In some cases.
GIS – geographic information system.
[a] Construction method description (from Table 3), installation record and/or inspection report by site manager.
[b] Inspection reports not required systematically but only in some permit decisions.
[c] Only GHEs made with a permit are included, not those made with a notification.
[d] Only GHEs made with an action permit are included, not those made with a building permit (new building).

(Table 5). In one of the municipalities there were no inspections at all, because the inspector "knew all the properties beforehand". There were also no inspections in the projects that had been processed as notifications.

As for the registration of GHE systems, seven of the nine municipalities had a map or a geographic information system (GIS) where they entered the GHEs with some degree of accuracy (Table 5). This was either the exact location of the GHE as recorded at inspections, or a tag that indicated the properties that had been granted a GHE permit or had filed a GHE notification.

4.4. Environmental impacts of GHEs and causes of permit rejection

The interviewees were asked to describe their observations regarding environmental impacts of GHEs. Two interviewees mentioned cases in which water wells on neighboring properties had dried up during BHE drilling. One interviewee also referred to artesian aquifers in his municipality.

Two municipalities reported that they had rejected some permit applications. In the first municipality, one application had been rejected because it was located on a designated groundwater area. In the second municipality, a few applications had been rejected either due to designated groundwater areas or to proximity of neighbors' water wells.

5. Discussion

The aim of this study was to identify good permit practices in relation to environmental protection, quality control and stakeholders' interests by comparing GHE permit practices between municipalities in Southwest Finland, and to find out how the current permit procedures advance the good of the different stakeholders.

The total number of studied applications and decisions in this study was rather large. However, in small and medium sized municipalities applications and decisions over a period of more than five years were studied, while in large municipalities only one year was studied. Thus, it is not possible to for example compare the absolute diversity of permit regulations. Also, comparisons of the handling times of applications are somewhat limited by this temporal constraint.

Regarding the population sizes of the municipalities, the number of the studied municipalities (nine) was relatively small for making far-reaching comparisons. Thus, the correlations between the municipalities' sizes and the various permit practices are indicative at most.

5.1. Good governance and the diversity of permit processes

In Majuri [5] Finnish geoenergy practitioners expressed concerns about the heterogeneous permit practices in different municipalities, long handling times of applications, and municipal officials' inadequate competence regarding geoenergy systems. The results of this study confirm that differences exist between municipalities, entailing a potential conflict with the impartiality requirement in Principle 5 of the Council of Europe's good governance guidelines [4]. Earlier studies have observed that heterogeneous permit practices complicate the adoption of renewable energies, for example in the UK regarding micro-wind turbines [24][] and in California in relation to small-scale solar and wind installations [49]. On the other hand, in Greece for example, the conditions, required documentation and procedures for the licensing of geoenergy systems are defined in a Ministerial Decree [20] which should promote relatively homogenous permit practices. From the perspective of both good governance and efficient adoption, a relatively uniform permit scheme would be recommendable.

Regarding retrofit GSHP projects, seven municipalities in this study implemented a permit procedure for GHEs, one had a notification procedure, and one applied both depending on location. The choice of procedure did not relate to the population size of the municipalities. Apart from the site plan, there were some differences in the documents required by municipalities as attachments to the permit applications (Table 3). These did not correlate with the population size of the municipalities either.

As regards electronic application systems, the small municipalities were the most advanced: all the small municipalities, two large and one medium sized had an electronic system by the beginning of 2018. We originally expected to find more advanced systems in the well-resourced large municipalities. In electronic application systems, obligatory fields and attachments ensure that the necessary information has been provided. This saves time and simplifies the application process for the clients, municipal administration, and geoenergy practitioners.

Handling fees for action permits regarding retrofit GHE installation varied between 100 and 350 €, that is by a factor of 3.5 (Fig. 3). The highest fee 350 € consisted of 150 € for the action permit and an additional 200 € for the location inspection. In this case, the location inspection was conducted by a different department (the field surveying) instead of the building control itself. In the other municipalities, possible location inspections were conducted by the building control, in connection with other inspections. The fees were on average higher in the large municipalities than in small and medium sized municipalities. In new buildings the permit for a GHE entailed an extra cost of 100–200 € in the large municipalities, while in the small and medium sized municipalities there were no extra costs in these cases.

The annual average handling times of action permit applications varied considerably between and within municipalities, but no clear trends relating to specific years or the size of municipalities emerged in Fig. 4. The studied applications were mostly handled in less than three weeks, and only 7% of decisions took more than five weeks to be issued. Thus, in the studied sample the handling times were for the most part reasonable and in accordance with Principle 2 of the Council of Europe's good governance guidelines [4].

The extent and content of permit regulations varied considerably between the municipalities. Likewise, measures to promote quality control varied between municipalities. Some municipalities required a site manager, a final inspection on site, and several documents such as a drilling log and a report on the installation. Other municipalities required none of these. The population size did not seem to define the municipalities' approach to quality control (Table 5). Instead, these differences reflected for example the different GHE experiences and knowledge base among the building control officials of the municipalities.

Regarding the qualifications of site managers, section 122c of the current Land Use and Building Act distinguishes between demanding, ordinary and minor supervision work, and defines the qualification requirements for each category separately [6][]. For *ordinary supervision work*, requirements are placed on the training and experience of the site manager. To undertake *minor supervision work*, no degrees are required but anyone who "*may be seen as having sufficient prerequisites*" is accepted. Thus, most of the studied municipalities placed GHE installations into this latter category.

'The duty to take care in building activities' [6] was reflected in the permit regulations of those municipalities that required the client to personally ensure that laws, orders, (municipal) regulations and permit regulations are observed, and that the construction work is sufficiently supervised and inspected. This requirement is challenging for non-expert clients. Principle 2 of the Council of Europe's good governance guidelines [4] states that procedures should be adapted to the legitimate needs of citizens. Indeed, the Ministry of the Environment has instructed that the extent of supervision by the municipal building control should be adapted to the level of expertise of the client, and that the need for public supervision increases when public interests are involved [50]. In the case of GHEs, groundwater protection unquestionably is an important public interest.

Practical ways to further assist the clients in fulfilling their duties and to advance system quality are (1) placing qualification requirements for the geoenergy installers and drillers, and (2) designing comprehensive national building regulations for GHEs. These measures were suggested by Majuri [5] based on concerns and opinions expressed by Finnish geoenergy practitioners, and they are in line with the notions of Heiskanen et al. [51]. Qualification requirements are commonly applied for example in the United States [21]. Also, in some Swedish municipalities using a certified driller is a prerequisite for a geoenergy permit [22]. These topics have been extensively discussed in various international projects [e.g. 52, 53]. However, currently no qualification requirements exist for geoenergy practitioners in Finland, and there are no national building regulations for GHEs either [25]. Thus, these should be promptly developed and incorporated into the permit scheme, which is the appropriate place to verify the practitioners' qualifications and their commitment to regulations.

While municipal autonomy leads to diverse permit practices, municipalities may also co-operate or copy from each other good governance practices for building control. There were some examples of neighboring municipalities having similar practices in some respects. For example, handling of drill cuttings and sludge was regulated only in the environmental protection regulations of one municipality and in the permit regulations of the neighboring municipality. Apart from this, in two cases the phrasing of the environmental protection regulations on GHEs were identical in neighboring municipalities.

5.2. The permit procedures from the perspective of different stakeholders

In many municipalities, **clients** received useful information during the permit procedure regarding environmental issues and adjoining properties, such as (1) distances that should be left between GHEs and various other objects, (2) groundwater protection, (3) quality and handling of heat transfer fluid, and (4) handling of drill cuttings and sludge.

The building control may also offer quality control support for the client. By requiring the nomination of a qualified site manager (e.g. a drilling contractor with verified qualifications), the building control promotes a professional quality approach. If the final inspection is conducted on site, a variety of technical details as well as the adequacy of operating guidance may be covered. The inspector gets a general overview of the quality of work and as a professional may point out possible deficiencies. Controlling the drilling logs and installation reports also serves this purpose.

Neighbors often have a role in the permit process since they are potentially affected by geoenergy systems. Neighbors may also have a role in representing the public environmental interest. Neighborhood issues have a long history in Finnish environmental legislation: already in 1879, locations of activities or industries that may cause environmental deterioration in the neighborhood were regulated [54]. The responsibility of supervising the control of such activities has been laid upon municipalities. In our material, six municipalities notified that they require neighbor hearings always or in certain situations. The positive effects of hearings are that they (hopefully) make the clients aware of the influence their geoenergy projects may have on others and provide the neighbors an opportunity to express their views and watch over their interests. However, although the neighbors have access to all the application documents, it remains unclear how well they in reality are informed in each municipality about the GHEs' possible influence on their property for example through heat extraction. Adequate information is particularly important if the neighbor is asked for a consent to a deviation from for example distance recommendations.

Distances from the GHEs to property borders, water wells and pipes, sewage treatment and pipes, and buildings are commonly controlled by the municipalities. The distances are an essential variable that has relevance for the neighbors, clients, and the functionality of the geoenergy system. The distances are also a property of the GHE that is easy to measure and understand. However, the minimum distance requirement between the GHE and property border should be sufficient. Geoenergy practitioners identified preventing uptake of heat from adjoining properties as one of the positive effects of the action permit scheme [5]. Some municipalities required 4–5 m between a BHE and property border, which is too little in this respect. The recommended distance between two BHEs intended to be thermally independent is 15 m in Finland and 20 m in Sweden where climatic and geological conditions are somewhat identical to those in Finland [48] p. 25, [23] p. 25]. Many practitioners prefer the 20 m distance also in Finland, and if the distance is below 20 m, it is recommended that this is compensated for by building a deeper BHE. Neighbor hearings are essential here to chart the locations of existing BHEs and to consider the neighbors' future needs.

Measures that promote the quality and safety of the GHE and its construction benefit also neighbors. In their interests would be for example requirements on handling of drill cuttings and sludge, and construction methods that advance groundwater protection.

With the permit or notification procedure, the **public administration** is now able to keep track of the locations and abundance of GHE systems. Unlike for example in Sweden [55], there is no borehole register in Finland. Thus, before the permit scheme took effect, the public authorities had little information regarding the constructed boreholes and geoenergy systems, or their locations. Maintaining a GIS or a map of GHE systems benefits, in addition to the building control, also the environmental authorities, surrounding property owners, geoenergy practitioners, and future property owners. Municipal authorities have also had a chance to enhance their control over groundwater protection, handling and deposition of drill cuttings, sludge and dust, and the location of GHEs in relation to public utility services.

Various studies have explored the risks that boreholes and GHEs pose to the **environment**, such as groundwater flow and contaminant transport through boreholes in multilayer aquifer – aquitard systems [56,57], and health hazards and environmental risks of antifreeze solutions used in geoenergy systems [28–30]. The environmental challenges relating to GHEs in Finland have also been studied [25]. Single cases of environmental problems relating to BHEs reported in Finland include for example contamination of domestic water wells caused by heat transfer fluid leakage [58] and damage by drill sludge in a creek that had been restored into a breeding habitat for trout [59].

Based on the municipal environmental protection regulations, it seems that the legal introduction of GHE permits in May 2011, and the Energywell handbooks [48,60] increased awareness and knowledge in municipalities of environmental issues relating to GHE systems: All the five municipalities that revised their environmental protection regulations after mid-2011, included details relating to GHEs. Conversely, those four municipalities with older environmental protection regulations still in force had no paragraphs on GHEs in their regulations.

The permit scheme enables the municipalities to regulate and draw the clients' attention to environmental and health issues that may be encountered in retrofit geoenergy projects. One municipality made use of this opportunity by instructing a procedure for handling old oil tanks when oil heating is replaced with geoenergy, and by reminding of the asbestos regulations if asbestos insulation has been used in the old plumbing.

Six municipalities notified that they have an established procedure for GHEs on designated groundwater areas (Table 4). This may not have been a relevant issue in some municipalities that have few designated groundwater areas and have not had GHE applications on those areas.

5.3. Permit rejections and geological challenges

The municipalities had rejected a few action permit applications due to designated groundwater areas or to proximity of neighbors' water wells. The small amount of rejections in municipalities may be explained by the fact that the permits for projects planned on designated groundwater areas are in most cases handled by the Regional State Administrative Agency. Moreover, clients tend to drop their projects rather than apply for permits from the regional administration.

Apart from designated groundwater areas, other geological

Table 6
Suggested good practices for a geoenergy permit procedure in Finland.

	Good practices
Application phase	Neighbor hearing (at least) if BHE <20 m from property border
	Neighbor consent if BHE <7.5 m from property border
	Geoenergy fact sheet to neighbors
	Independent BHEs ≥15 m apart (designer defines spacing within a BHE field)
	Nomination of a qualified site manager
	Verification of the professional qualification of geoenergy contractor(s)
Construction phase	The following are instructed e.g. in permit regulations:
	Building regulations for GHEs, e.g. methods and structures for groundwater protection, handling of drill cuttings, quality and handling of heat transfer fluid
	Dismantling of old oil tanks and asbestos insulation in retrofit projects
After completion	Final inspection on site by the municipal building inspector
	Inspection of drilling logs and installation reports by the building inspector
	Municipal building control maintains a GIS or a map compilation of GHEs

challenges that came up in the interview surveys included dried up water wells and artesian aquifers. Previous experience of dried up dug wells possibly explains why one of the municipalities had rejected some GHE permits based on the proximity of neighbors' water wells. The topic appeared also indirectly in the permit regulations in this municipality, phrased as "*the licensing authority is not responsible for possible groundwater changes*". Dried up wells often result from a combination of an inexperienced or hasty driller drilling in demanding geological conditions that would require special attention and methods [26]. The drying is usually temporary, and the groundwater table will be gradually restored.

Artesian water usually causes moderate or little damage in Finland since the pressures are not very high [25]. As the effects are typically temporary and controllable, municipalities would rarely need to reject GHE permits based on artesian water, and this had not been done in the studied municipalities either.

6. Conclusions and policy implications

The general benefits of renewable energy permit schemes include monitoring and registering new installations, and direct possibilities to introduce new environmental safety precautions to installation projects. Importantly, a permit scheme is often an essential link between the legislation and installation practice. Such benefits are consistent with the objectives listed in the Council of Europe's principles of good governance.

Our study found considerable differences between Finnish municipalities in their permit procedures related to installation of geoenergy. The clients in different municipalities do not receive equal treatment in terms of for example handling times, processing fees, or support for quality control. To develop the permit schemes and improve governance, earlier studies and reports have called for a national standard that would simplify, speed up and harmonize the permit processes. In addition to speed and simplicity, other objectives must also be kept in mind and incorporated into the permit procedure. Such objectives include promoting environmental and groundwater protection, safeguarding the neighbors' interests, and supporting the clients in quality control. These objectives are mostly statutory and promoting them is also a top priority for the geoenergy industry, which needs to retain its reputation and credibility. Our study identified several good practices in relation to these objectives (Table 6).

Principle 7 in the Council of Europe's [4] good governance guidelines states that the professional skills of those who deliver governance should be continuously maintained and strengthened to improve their output and impact. Thus, to promote good governance and equal treatment of clients, building inspectors need detailed, field-specific instructions for handling geoenergy permits. Although the municipal autonomy is wide in Finland, and environmental conditions vary in different parts of the country, not all municipalities have the resources to develop their own instructions. Additionally, the interviewees expressed a need for more guidance on for example handling of problematic or special cases; clearly such support can only be provided by geoenergy specialists.

CRediT author contribution statement

Pirjo Majuri: principal author, Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Visualization, Writing - original draft, Writing - review & editing. **Anne Kumpula:** Conceptualization, Formal analysis, Supervision, Writing - original draft, Writing - review & editing, legal expert. **Timo Vuorisalo:** Conceptualization, Formal analysis, Funding acquisition, Investigation, Supervision, Writing - original draft, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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APPENDIX

Outline of the interview survey for municipal building control officials on geoenergy permits.

1. **Does the municipality apply a permit procedure or a notification procedure?**
2. **Application process and practices**
   How is the permit applied for: Do the clients require personal guidance? Are the applications submitted on paper or electronically? What documents are needed?
   Are the instructions and forms available on the municipality website?
   Has the application procedure changed since 2011?
   Is there an inspection on site, and if so, when? What are the focal points of inspection?
   What is the processing fee for the application? Are there any additional expenses for the client?
3. **Preconditions**
   What are the preconditions (if any) in the municipality for granting the permit?
4. **Quality control and permit regulations**
   Does the building inspector control the quality of the design or construction of the geoenergy systems? How?
   In the permit decisions, are there regulations for the construction of the GHEs? Examples? Rejecting the permit vs. tighter permit regulations.
   Have there been GSHP projects in the municipality that required and applied for a permit from the Regional State Administrative Agency in accordance with the Water Act? Experiences?
5. **Environmental impacts of geoenergy and proficiency of practitioners**
   Observations on the environmental impacts of geoenergy systems
   Observations on the proficiency of the geoenergy practitioners
6. **Instructions and training**
   Did the inspector receive sufficient instructions and training for processing geoenergy permits?
   Opinions on the Energywell hand book? How and for whom should it be developed?

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