Ground source heat pumps and environmental policy – the Finnish practitioner's point of view

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Abstract

Since the 1970s energy crises, and increasingly in recent years, ground source heat pumps have attracted large interest as an instrument for energy conservation. Rapid growth of the industry has raised questions about the environmental benefits and costs of heat pumps. Governments have designed policies to both promote and regulate the industry. This study concentrates on the development of the ground source heat pump industry in Finland, and on national policies and regulations concerning the industry. The focus is on practitioners' responses to heat pump legislation, a topic so far overlooked by researchers, but also the users' perspective is considered. The study is based on interviews and questionnaire responses from heat pump professionals, heat pump statistics, and literature. Six sectors of legislation and environmental policy are considered: the regulation of ozone depleting substances and greenhouse gases in refrigerants, qualification requirements imposed on the ground source heat pump industry, the permission procedure for ground loop heat exchangers, legislation on groundwater protection, requirements and incentives for heat pump efficiency and labelling, and public funding and subsidies for the industry. The results show that policies have an important role in the development of the industry, and that quality aspects deserve more attention in policies regarding e.g. GSHP training and planning permissions.

1. Introduction

The idea of ground source heat pumps (GSHPs) was first presented more than a century ago by a Swiss turbine engineer Heinrich Zoelly (Zogg 2008:13). GSHPs are used to extract heat from ground loop heat exchangers, either vertical (borehole) or horizontal, and deliver it for heating the house and sanitary water. In Finland, the first experimental GSHP systems were installed in the 1950s (Karjalainen 1959). Finland is located in northern Europe and due to the long and cold winters the need for heating is substantial. Oil, electrical, wood and district heating with varying proportions have been the dominant sources of heating in northern Europe over the past 50 years.

During the 1970s the world experienced the so-called oil crises that launched a great global interest in alternative energy sources, including GSHPs. Two decades later, the growing climate concern and increasing need for energy security prompted governments in different countries to design policies with consequences also for the GSHP industry. For instance, in Sweden research funding was strong, and a public procurement program (1993–1995) was organized by an administrative authority to promote the development of more efficient, reliable and less expensive GSHPs (Nilsson et al. 2005). Meanwhile, the Swiss Federal Office of Energy launched a heat pump promotion programme, which began with the establishment of the Swiss Heat Pump Association (1993), and continued through financial support for projects that promoted quality, training and marketing within the heat pump industry (Rognon 2008). The Swiss canton of Zurich, followed by most of the other cantons, adopted in 1997 legislation that restricted the share of non-renewable energy for heating in new buildings, which contributed to the deployment of heat pumps (Kiss et al. 2012). Similarly, the Republic of Korea adopted a law in 2004 that required new and

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reconstructed public buildings to have new and renewable energy systems installed, and consequently, in 2004–2007, 60% of new public buildings were equipped with a GSHP system (Lee 2009). The rapid growth of the GSHP industry has raised questions about the environmental benefits and costs of GSHPs. For instance, the renewable energy production, carbon footprint of GSHP systems as well as geothermal potential of aquifers have been intensively studied (e.g. Arola et al. 2014; Arola & Korkka-Niemi 2014; Bayer et al. 2012; Laitinen et al. 2014; Mattinen et al. 2014).

In Finland the governmental interest in heat pumps arose later and has been less consistent than in Sweden and Switzerland. Finland's energy policy programme from 1979 mentioned heat pumps alongside solar and wind energy, and stated that the utilization of and research into these alternative energy sources will be promoted (Energy Policy Council 1979:9). The next Energy Policy Programme (1983:18) declared that efforts will be made to develop more economical heat pumps for small and large scale applications. However, these efforts never materialised, and research funding was terminated. Heat pumps were not even mentioned in the Finnish energy strategies and energy committee reports in the late 1980s or in the 1990s (Energy Committee 1989; MTI 1992 & 1997). The Climate Strategy of 2001 contained only one sentence that referred to heat pumps: "The use of heat pumps, inter alia ground source energy, will be promoted" (MTI 2001).

However, in the Finnish Advancement Programme for Renewable Energy 2003–2006 heat pumps received more attention than in the earlier programmes. In this programme heat pumps were already considered a noteworthy source of renewable energy, and a tool for reduction of CO_2 emissions, and an investment subsidy was suggested (Working Group on Renewable Energy 2003:43,50). In 2005 the National Strategy to Implement the Kyoto Protocol stated that "the utilisation of heat from the environment… through the use of heat pumps has proceeded positively" (MTI 2005:26). The Long-term Climate and Energy Strategy of 2008 set a 5 TWh target for renewable energy production by heat pumps in 2020 (MEE 2008:48). Interestingly, a much earlier report had presented a scenario of 5–6 TWh of GSHP energy for the period 2020-2030 in Finland (Joensuun korkeakoulu 1983:25). The National Energy and Climate Strategy of 2013 listed heat pumps as one of the tools in decreasing the use of fossil fuels in heating (MEE 2013:19,51). The Energy and Climate Roadmap 2050 stated that "ground source energy can be utilised much more than at present" but did not set any targets for GSHP energy production (PCECI 2014:13). Lund (2007a) has suggested introducing a renewable energy quota as well as higher energy efficiency standards for Finland. The building regulations in Finland have aimed at progressively improving insulation levels of constructional elements, whereas no regulations to promote renewable energies have been introduced in spite of explicit requirements in the RES Directive (2009/28/EC, Article 13).

This paper aims to provide an analysis of the Finnish GSHP energy policy primarily from the perspective of practitioners. The practitioners are here defined as the personnel and companies that install or design GSHP systems. The stakeholder network in energy policy includes policy makers and administration, practitioners and users. Numerous studies have highlighted the importance of stakeholder participation in policymaking, e.g. to gain broader understanding of the issue, and to improve acceptance of the developed policy measures (e.g. van den Hove 2000; Driscoll & Starik 2004; Santos et al. 2006).

The users' perspective to the heat pump sector, and generally energy-efficient technologies, has been widely studied. For example, Heiskanen and Lovio (2010) found that the reciprocal exchange

of information about users' needs and manufacturers' capabilities needs to be improved. Information provided by manufacturers is sometimes received with suspicion, while the views and experiences of friends and opinion leaders in the community are trusted more (e.g. Stern 1992; Nair et al. 2010; Heiskanen & Lovio 2010). Limited or costly availability of reliable information is also among the barriers to energy-efficient investments by enterprises. Other barriers include low priority and high hurdle rates (e.g. DeCanio 1993; Rohdin & Thollander 2006; Meath et al. 2016).

Stern (1992) highlighted the concept of problem avoidance in the context of promoting the diffusion of energy-efficient technologies. From the users' point of view this involves high quality of the systems, and simple shopping processes. In Finland a lot remains to be done in both respects. In their analysis of heat pump users in Finland, Heiskanen et al. (2014) pointed to "limited standards and the early stage of certification systems and advice by the public sector". They continued by listing the challenges these circumstances present for users: the users should, for example, make sure the products and service providers are competent and their plans are realistic, monitor the installation, and monitor and adjust their heat pump systems.

This paper investigates (1) the development of the Finnish GSHP policy and its instruments, and (2) the success of the Finnish governmental energy policy from the GSHP practitioners' perspective. I also discuss the solutions to the observed problems in implementation of energy policy objectives in the GSHP sector from both the users' and practitioners' perspectives. Several international projects have analysed the existing shallow geothermal legislation and GSHP standards at European level, and the need to develop and harmonise these regulations (e.g. Ground-Reach 2008; GEO.POWER 2012; REGEOCITIES 2013; Hähnlein et al. 2013). The focus of this paper on practitioners can be justified by their omission from most earlier studies on GSHP policies. For instance, in their study of the regulations on the use of shallow geothermal energy, Haehnlein et al. (2010) sent a questionnaire to several countries, but practitioners were not included in the respondents. Due to close historical links in the development of the GSHP industry between Finland and Sweden, some Swedish data are included in the analysis. Switzerland is also used as a point of comparison because of its different policy approach and strong GSHP traditions

2. Materials and Methods

In this study a questionnaire study, interviews of heat pump professionals, heat pump statistics and literature were used to collect (1) information on the development of the industry in Finland, and (2) the practitioners' views on the GSHP policies and their implementation. Legal texts were analysed to document the development of the legislation and policies.

2.1. Questionnaire study

The questionnaire made it possible to collect experiential knowledge and views from a large sample of heat pump professionals. The questionnaire was titled 'Observations and practices within the ground source heat pump industry in Finland'. It was targeted at contractors installing GSHP systems, or drilling and installing borehole heat exchangers, and engineering offices designing GSHP systems. The design of the questionnaire was based on Vastamäki (2007), and Frankofort-Nachmias & Nachmias (1996:249-278). The questionnaire was carried out from January to March 2014 using Webropol online survey and analysis software. To obtain maximum coverage six different organizations working with the heat pump industry assisted in distributing the questionnaire link to their members, and also 126 unorganized companies were contacted directly by e-mail. Two e-mail reminders were sent to the recipients.

The questionnaire (Appendix B) contained a wide variety of questions dealing with for instance building practices, observed environmental impacts and malfunctions, and the respondents' experience and views of the legislation, control, and practices of the GSHP industry. In this article the emphasis will be on the respondents' experience and views that they expressed in the open-ended questions.

The obvious problem with the applied distribution system is that the absolute number of questionnaire recipients is unknown as the questionnaire link was delivered freely by the organisations, and further on by their members. This method was chosen to guarantee wide sub-sectoral and geographical coverage; the aim was that all practitioners in the sector in Finland would have a possibility to participate.

2.2. Thematic interviews

The purpose of the interviews was to collect the professionals' insights and in-depth information that has not been previously recorded. Seven Finnish heat pump professionals representing different viewpoints to heat pumps were interviewed (Table 1.). Random sampling of interviewed persons was not possible due to the very small number of pioneers in the field in Finland. Instead, the interviewees were selected on the basis of their long professional careers and exceptionally wide experience in the field (Table 1.).

The interview design and outline (Appendix A) were based on Eskola & Vastamäki (2007), and Rubin & Rubin (2005). The length of the interviews varied from 37 to 113 minutes. The interviews were recorded and transcribed afterwards using a word processor.

Table 1. The heat pump professionals interviewed for thematic interviews.

	Description	**Date of interview**
Interviewee 1	A retired academic teacher from a technical university in Finland, has researched various heat pump topics since the 1970s	5 May 2014
Interviewee 2	One of the founders of Suomen Lämpöpumpputekniikka, the oldest heat pump factory still operating in Finland; in the 1970s worked also for Lapuan Yleishiomo, the first heat pump factory in Finland	5 May 2014
Interviewee 3	An engineer and a founder of Enersys, a heat pump design company; a pioneer in the design of large heat pump systems in Finland, also involved in many research projects	20 May 2014
Interviewee 4	A retired borehole and heat pump contractor, worked with well drilling between 1970 and 2013; drilled one of the first borehole heat exchangers in Finland in 1983–84	20 May 2014
Interviewee 5	A borehole and heat pump contractor, the first chairman of the Finnish Well Drillers' Association in the 1990s	3 June 2014
Interviewee 6	The executive director of the Finnish Heat Pump Association; worked with heat pump imports from the 1990s until 2011; had a central role when the association was established in 1999	3 June 2014
Interviewee 7	A retired refrigeration contractor who worked with heat pump service	24 April 2014

2.3. Statistics and literature

The sales statistics were used to get an overview of the development of the GSHP industry. The statistics were supplied by the Finnish Heat Pump Association (SULPU, www.sulpu.fi) and its Swedish counterpart, the Swedish Refrigeration and Heat Pump Association (SKVP, www.skvp.se). SULPU provided the Finnish sales statistics it started to collect from ground source heat pump factories and importers after its establishment in 1999, and estimates on sales figures

for the period 1976–1998. SKVP provided the Swedish sales statistics since 1982. Although not official documents, such sales statistics are the only available data on the topic, and presumably provide a relatively good overall picture of sales trends. Similar data have earlier been used by e.g. Nilsson et al. (2005) and Kiss et al. (2012).

GSHP literature provided contemporary viewpoints and information from the various decades. The Finnish National Library's article reference database Arto (https://arto.linneanet.fi) yielded 117 heat pump articles from Finnish professional and popular journals between 1960 and 2013. However, only a few of the articles proved useful from the viewpoint of this article.

2.4. Legislation

Six sectors of legislation that have influenced the development of the GSHP industry in Finland were considered: (1) the regulation of ozone depleting substances and greenhouse gases in refrigerants; (2) two types of qualification requirements imposed on the GSHP trade: the refrigerant qualification, and the qualification of truck drivers; (3) the planning permission scheme for ground loop heat exchangers; (4) legislation on groundwater protection; (5) the EU legislation that sets requirements and incentives with impacts on the heat pump industry; and (6) public subsidies applied to the heat pump sector.

3. Results

3.1. Growth of the GSHP industry in Finland

After the first energy crisis GSHP sales grew steadily in Finland from the mid-1970s to the early 1980s (Fig. 1.). Funding for energy research increased considerably in Finland following the 1973 energy crisis. The Energy Department at the Ministry of Trade and Industry granted research financing open-handedly also for heat pump research for several years (Interviewee 1). Also some GSHP factories, for example Lapuan Yleishiomo, received funding from the Finnish Innovation Fund Sitra (Interviewee 2). In the early 1980s there were 15 GSHP factories in Finland, most of them small "garage workshops" (Interviewee 2). Many of them had insufficient expertise, and the poor quality of their products seriously harmed the reputation of the whole industry (Interviewee 1). Moreover, the energy crises were over at that time, and the power and oil companies entered in a fierce competition on heating market shares that led to a relative decrease in energy prices (Fig. 1.), which further reduced the competitiveness of heat pumps (Interviewee 6). Due to poor reputation and intense competition, by the end of 1983 the original 15 GSHP factories had all gone bankrupt or otherwise out of business, and the trade remained at a very low level until the mid-1990s.

During the second half of the 1980s also funding for heat pump research had run out. In a newspaper interview in 1989 professor Antero Aittomäki called for more far-sighted thinking from the Ministry of Trade and Industry that had abandoned heat pump research for failing to produce fast-selling applications in the unfavourable circumstances of the energy market (Laine 1989). At the turn of the decade the Ministry awarded funding for heat pump research in the Future Building Services Research Programme (Aittomäki & Viita 1992). Later on (1993–1998) heat pump development received funding through the RAKET research program, which investigated the energy use of buildings (Lehto 2001:33).

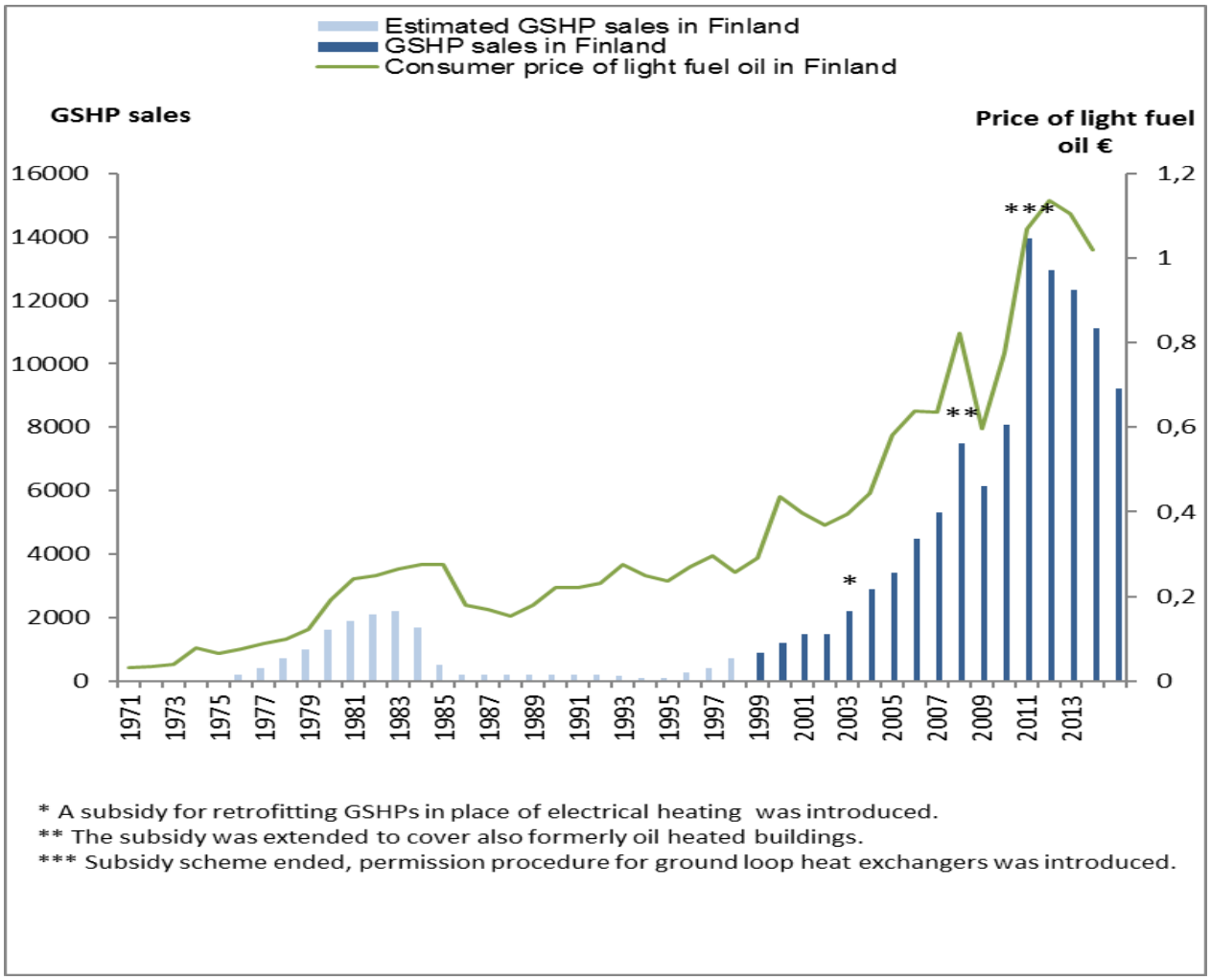

Figure 1. Ground source heat pump sales and the consumer price of light fuel oil in Finland. Data from the Finnish Heat Pump Association, Myllyntaus (1999) and Official Statistics of Finland (2016).

Towards the end of the 1990s the GSHP industry started to recover in Finland. There were two Finnish brands established in the 1980s, i.e. Lämpöässä heat pumps (produced by Suomen Lämpöpumpputekniikka Oy), and Ekowell heat pumps (Interviewee 2; Lehto 2001:62). The Swedish brand Thermia had been on the Finnish market already in the 1970s, and continued its sales. Also new Swedish brands such as IVT and Nibe entered the market in the 1990s. This time the market growth was on a more solid foundation due to more advanced technology and distribution channels. Most of the heat pump suppliers began to build a retailer network of specialised contractors in the 1990s (Interviewee 6). The Finnish Heat Pump Association (SULPU) was founded in 1999 to distribute information, defend the interests of the industry, promote quality, and develop training. Construction of borehole heat exchangers increased markedly in the 1990s, which made the use of ground source energy possible on smaller and rockier building lots, and thus multiplied the amount of potential customers. Since the mid-1990s the GSHP sales increased consistently for over fifteen years (Figure 1.). According to Statistics Finland (2016) the proportion of houses with GSHP installed increased tenfold from 0.26% in 2000 to 2.74% in 2014.

Figure 2. compares the GSHP sales between Sweden and Finland. The heat pump trade took off faster in Sweden, but according to Interviewee 1, in the 1970s the flow of information was at some stage from Finland to Sweden: When the Finnish researchers first modelled the interactions

between the ground and ground loop heat exchangers “the Swedish experts came to us for advice”. However, Interviewee 1 noted that the Swedish Aga Thermia then began to invest considerably in the development of its heat pump models. Other producers followed, and Sweden developed into one of the leading GSHP countries in the world.

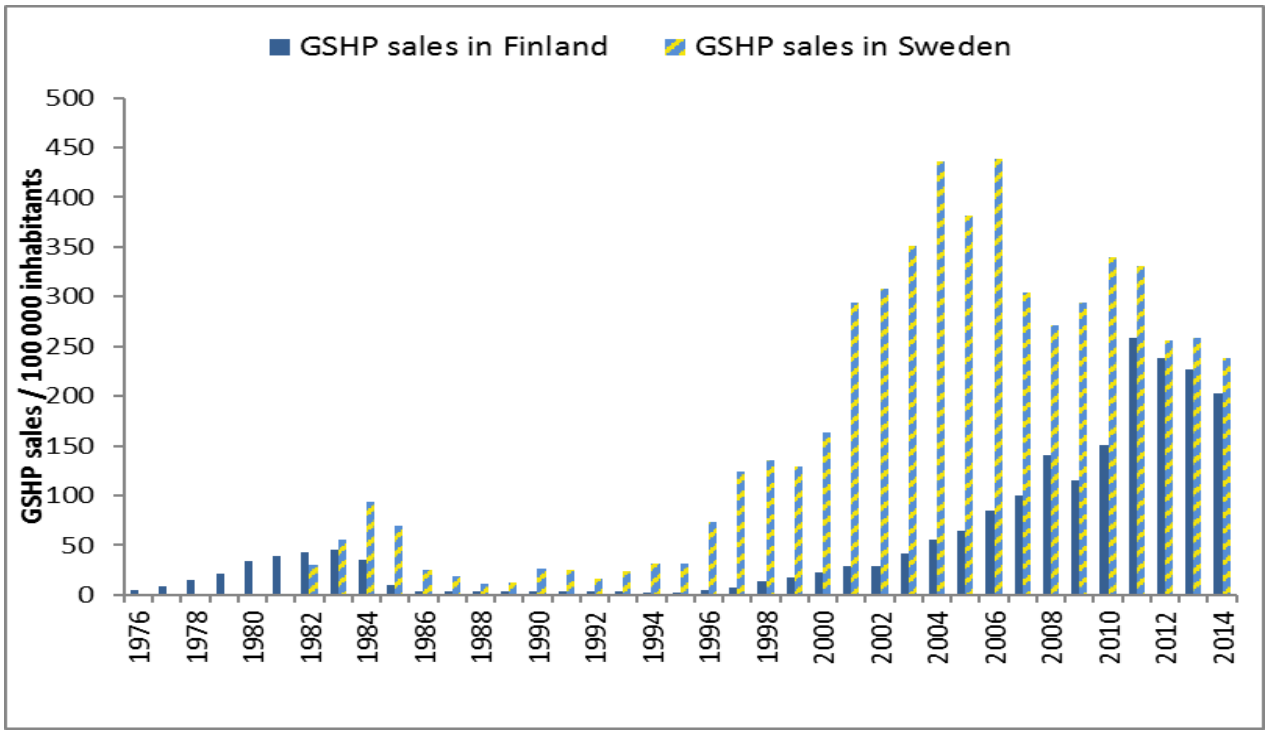

Figure 2. Ground source heat pump sales per 100 000 inhabitants in Finland and Sweden. Note that the Finnish sales figures for 1976-1998 are estimates, and that in Sweden more than 13 500 GSHPs had been sold by the end of 1981. Data provided by the Finnish Heat Pump Association and the Swedish Refrigeration and Heat Pump Association.

3.2. Regulation of GSHP industry and technology

The effects legislation has had on the GSHP industry in Finland, and the statutes cited in this article are summarized in Table 2., and the properties and use regulations of some refrigerants in Table 3.

A decree that controls the service of devices containing ozone depleting substances and F-gases came into effect in Finland in 2009 (Finnish statute 452/2009). This decree required (1) GSHP contractors to employ a person in charge who has an applicable refrigerant training or qualification, and (2) every GSHP installer to have an applicable refrigerant qualification.

Table 2. Legislation affecting GSHP industry in Finland.

Impact on the GSHP industry	Statutes
Regulation of ozone depleting substances and greenhouse gases in refrigerants	**The Montreal Protocol** **Finnish statute** 677/1993 (Government Decision on Restricting the Use and Import of Fully Halogenated CFC Compounds etc.) **Finnish statute** 262/1998 (Government Decision on Substances that Deplete the Ozone layer) **Regulation (EU)** 517/2014 on fluorinated greenhouse gases
Obligatory refrigerant qualification	**Finnish statute** 452/2009 (Government Decree on the Servicing and Maintenance of Devices Containing Ozone Depleting Substances or Certain Fluorinated Greenhouse Gases)
Qualification of truck drivers	**Finnish statute** 273/2007 (Act on the Professional Qualifications of Truck and Bus Drivers)
Planning permission for ground loop heat exchangers	**Finnish statutes** 132/1999 and 895/1999 (Land Use and Building Act, and Decree), amendment 283/2011
Groundwater protection	**Finnish statute** 587/2011 (the Water Act) **Finnish statute** 527/2014 (the Environmental Protection Act)
Heat pump training, efficiency and labelling	**Directive** 2009/28/EC on the promotion of the use of energy from renewable sources (RES Directive) **Commission delegated regulation** (EU) 811/2013 regarding the energy labelling of heaters
Subsidies for heat pump installations	**Finnish statutes** 1021/2002 and 57/2003 (Act and Government Decree, respectively, on Residential Renovation and Energy Saving Grants) **Finnish statute** 115/2008 (Government amendment to the Decree on Grants for Residential Renovation, Energy Saving and Health Standard Improvement) **Finnish statute** 1255/2010 (Government amendment to the Decree on Grants for Residential Renovation, Energy Saving and Health Standard Improvement) **Finnish statute 1535/1992** (Income Tax Act), amendment 995/2000

Table 3. Properties and use regulations of some refrigerants. Data from Calm & Hourahan (2007), and Regulation 517/2014/EU.

	Ozone depleting potential	Global warming potential	Notes
CFC-11	1.000	4600	Use forbidden as heat carriers in new devices since 1995 in Finland (Finnish statute 677/1993)
CFC-12	0.820	10600	
HCFC-22	0.034	1700	Use forbidden as heat carrier in new devices since 2000 in Finland (Finnish statute 262/1998)
HFC-134a	0.000	1430	Reduction target 79 % in terms of CO_2 equivalents by 2030 (EU Regulation 517/2014)
HFC-404A	0.000	3922	
HFC-407C	0.000	1774	
HFC-410A	0.000	2088	

At EU level, the RES Directive (2009/28/EC, Article 14) requires that certification or qualification schemes are available (but not obligatory) for installers of shallow geothermal systems, and that guidance is available for planners and architects. The European Heat Pump Association coordinates the training and certification scheme EUCert, developed in accordance with the RES Directive. 13 countries have joined the EUCert programme, including Finland and Sweden (EHPA 2016). In Finland the obligatory refrigerant qualification for devices with less than 3 kg of refrigerant has been incorporated into the 12-day EUCert training. However, for GSHPs with more than 3 kg of refrigerant, the person in charge should have a vocational degree in refrigeration technique, which for most GSHP practitioners means several months or years of studies, depending on their previous training. Meanwhile there are no qualification requirements for the construction of boreholes, but the Finnish Well Drillers Association has developed a vocational degree programme for well drillers jointly with a vocational education centre (Poratek 2015a).

Another statute relating to qualifications within the heat pump and borehole industries in Finland concerns the qualification of truck drivers (Finnish statute 273/2007). It appears subject to

interpretation, but many contractors have decided to have their staff trained if they need to drive heavy vehicles.

Since 2011 the land use and building legislation in Finland has required that the house owner applies for a planning permission for minor construction before building a ground loop heat exchanger (amendment 283/2011, Finnish statutes 132/1999 and 895/1999). The act states that a municipality may in its building code ordain that a permission is not needed if the project is deemed insignificant, but this option has been utilized in few municipalities. The 2015 government program of Finland framed that the permission procedure should be simplified into a notification procedure (Prime Minister's Office 2015: Annex 4).

The construction of GSHP systems on important groundwater areas require a further permit in accordance with the Water Act (Finnish statute 587/2011). The Environmental Protection Act (527/2014) prohibits the pollution of groundwater with either substances or energy. No further regulations, e.g. limits for temperature change, have been issued. Instead, in each case the permit conditions should include appropriate instructions for the particular project. There are no binding regulations for the construction of ground loop heat exchangers either.

The RES Directive (2009/28/EC) legally recognises a renewable energy status for certain heat pumps: When calculating the share of energy from renewable sources, heat pumps with seasonal performance factors (SPFs) above a defined limit are taken into account. This limit depends on the EU average conversion efficiency of electricity generation. If for instance the conversion efficiency is 45 %, the required SPF for heat pumps is 2.56. At least in the North European market, most GSHPs exceed this level. Based on EU regulation 811/2013 all heat pumps have to be energy labelled from September 2015.

Heat pump installations have been subsidized by the Finnish public administration already at the beginning of the 1980s. Higher state-subsidized housing loans were available for houses with heat pump heating. Direct subsidies were also granted to heat pump retrofit installations (Junni 1980, Anon. 1980). With the plunge of the industry, the subsidies were abolished.

During the 1990s, climate protection gained increasing significance in international policy making resulting in obligations for individual countries. As part of meeting these obligations, the Act on Residential Renovation and Energy Saving Grants was enacted in 2002 (Finnish statutes 1021/2002 and 57/2003). State subsidies of up to 10% of the investment could be granted for retrofitting GSHPs into previously electrically heated dwellings. Amendment 115/2008 made it possible to subsidize also retrofitting GSHPs into, for instance, previously oil heated dwellings. The allocation of funds for the subsidy was decided separately every year. After 2011, another amendment (1255/2010) removed GSHP installations from the list of subsidized measures. In 2012 the state budget contained a much reduced allowance for the subsidy, and after that it was terminated.

Tax deduction for household and renovation work has been available in all of Finland since 2001 (Finnish statute 995/2000). In GSHP installations it is applied to the costs of person-hours and machine work but not the appliances and materials.

3.3. Interview and questionnaire data: the practitioners' perspective

The number of questionnaire respondents was 64. In the open-ended questions, 49 respondents made comments that have been included in this section. Figure 3. shows the distribution of

questionnaire respondents by field of operation and by geographical location. 55 respondents represented companies that install GSHP systems, borehole heat exchangers, or both. Due to the applied open distribution system the absolute number of questionnaire recipients is unknown. Hence, no accurate estimate of the response rate can be provided. According to the Finnish Heat Pump Association and the Finnish Well Drillers' Association there are approximately 300-500 companies that at least occasionally install GSHPs, and 70-80 borehole contractors in Finland (personal communication with Jussi Hirvonen; Poratek 2015b). It is not known how many of these companies actually focus on GSHPs in their business activities.

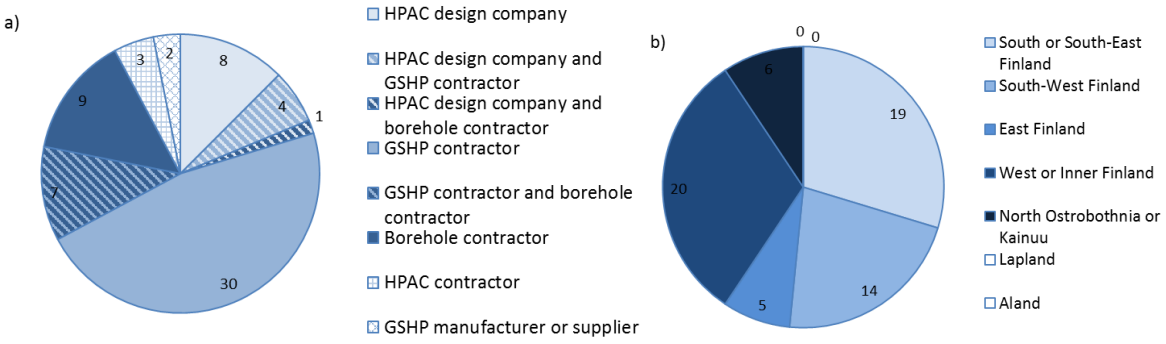

Figure 3. The profile of the questionnaire respondents (a) by field of operation (HPAC denotes Heating, Plumbing and Air Conditioning), and (b) by geographical location.

The practitioners made only few comments on the CFC regulations. Interviewees 2 and 4 briefly mentioned that HFCs do not perform as well as HCFC-22 in GSHPs. For example, their superheating properties are of lower quality.

The topic of training and qualifications evoked mixed responses. Ten respondents either expressed their concern about the unqualified installers in the GSHP sector or called for better training or qualification requirements for the practitioners. On the other hand, Interviewee 5 considered the refrigerant qualification unnecessary as GSHPs are hermetically sealed, and the installers do not need to handle refrigerants at all. One respondent suggested that especially the higher qualification requirements for devices with more than 3 kg of refrigerant should be abolished. Notably several respondents criticised the lack of enforcement of this decree. Nine respondents highlighted the importance of law enforcement and overall supervision. One suggestion was that the distributors would be obliged to ensure the buyer's qualification before selling a heat pump (Interviewee 5). A parallel control system has been successfully applied to refrigerant trade.

Interviewee 5 also took up the truck driver qualification. He stated that it serves no purpose, and that it is expensive and time consuming. The strenuousness of the qualification requirements has been accentuated by the fact that they have all been introduced within a few years. Interviewee 5 felt that "we need to spend more time attending trainings than doing our actual work".

Many practitioners approved of the need for a control mechanism concerning ground loop heat exchangers: in built-up areas the positioning of borehole heat exchangers should be carefully considered so that heat is not extracted from adjoining properties (e.g. Interviewee 4), and the safety zones between for example boreholes and small-scale sewage treatment should be ensured. However, the permission procedure received criticism from the questionnaire respondents that can be summarised into the following proposals for improvement: permission

practices in all municipalities should be explicit, practical and standardized (15 respondents); permissions should be processed smoothly and swiftly to avoid excessive delays in building projects (5 respondents); and permit issuing authorities should receive better training and detailed instructions regarding the construction of GSHP systems (6 respondents). Two respondents suggested that a notification procedure could be introduced instead of the permission procedure. On the question of how much work the planning permissions for borehole heat exchangers cause for their companies, 22% of the questionnaire respondents (N=63) replied “much work”, 56% “some work” and 22% “not at all”.

The questionnaire respondents did not comment on the current groundwater regulations. However, 62% of all the respondents (N=63) thought that the planning permission should require borehole heat exchangers to be built following certain standards. 16% were against standards, and 22% had no opinion. The attitudes differed between the fields of operation so that 47% of the borehole contractors (N=17) were in favour and 29% against standards whereas 92% of the HPAC designers (N=12) were in favour and none against the standards. Some respondents called for qualified official supervision of GSHP installations in general, and sizing of ground loop heat exchangers in particular to promote quality and functionality.

In the questionnaire and interviews opposing views were presented on the 2003–2011 direct subsidy scheme. The positive aspects of the subsidy were that it increased the demand for GSHPs (Interviewees 4 and 6), and that GSHPs received publicity every year during the application period (Interviewee 2). The 72% rise in GSHP sales in 2011 was partly caused by the announcement that the subsidy would end that year. Interviewee 6 argued that the surge in 2011 kept the sales for several years afterwards at a much higher level than what they would have been otherwise.

On the other hand, some professionals criticized the 2003–2011 direct subsidy scheme. The following sequence of problems was identified:

(1) When the next year’s subsidies were publicized, heat pump trade halted and customers remained waiting for the application period to begin.
(2) As there was only one application period per year so that all the applications had to be submitted in April, tendering was backlogged every year from February to April.
(3) If the customer had applied for the subsidy, installations could not be initiated until the subsidy resolutions had been made.
(4) Many new contractors entered into the trade within a short period of time with high hopes and little expertise, which led to defective installations.
(5) Overcapacity caused fierce and unhealthy price competition during times of low demand, and especially after the subsidy scheme had been abolished.

Problems (1)–(3) caused sharp fluctuations in demand: Sometimes the sales staff had more work than they could handle. Meanwhile installers had little to do, and some months later they, in turn, were all overworked. The periods of high demand led to problems (4) and (5). Consequently, many contractors seem to be happy to have no subsidy scheme at all.

In the open ended question “How does the competition present itself?”, 35 respondents mentioned price competition, and 28 of them explicitly used the expressions ‘price dumping’, ‘under-pricing’ or ‘price competition at the expense of quality’. Meanwhile 23 respondents expressed their concern about quality problems.

The tax deduction for household and renovation work was mentioned as a good way of subsidizing heat pump trade. The positive aspects of the tax deduction are that it has been reasonably

predictable, and it has encouraged customers to choose companies that operate within the law instead of the black economy (Interviewees 5 and 6).

4. Discussion

4.1. Factors behind the development of the GSHP industry in Finland

It seems that in the 1970s and 1980s the development of the GSHP industry in Finland was mostly directed by the energy price and internal factors of the industry, while legislation still had a minor role. The most effective measure by the public sector was research funding. The GSHP industry rose in the 1970s aided mainly by the energy crises that led to high oil prices and public research funding, and fell in the 1980s as a result of defective technology and installations.

Based on Figure 1., it seems that even the decreasing oil price was a secondary factor in the fall of the industry since the original Finnish heat pump factories had gone out of business already two years before the oil price started to decline in 1985. Likewise, the heat pump sales in Switzerland halved between 1980 and 1982 as a result of quality problems (Rognon 2008). In Sweden the heat pump trade declined after 1984 (Fig. 2.). Also in Sweden the heat pump industry was losing its reputation due to quality problems, but the sales were supported by a subsidy scheme for private households until 1984 (Nilsson et al. 2005).

In the 1990s the market situation, the societal atmosphere and public attitudes began to develop in a more favourable direction for the heat pump industry in Finland. This was in part caused by the strong emergence of sustainable development and climate policies that emphasized the future role of alternative energy sources (Kivimaa & Mickwitz 2011). Also the good success in Sweden encouraged and directed the Finnish GSHP sector.

Based on the results of this study, the development of the industry since the 1990s has been shaped by at least the following factors:

(1) Developing technologies: The GSHPs that were on the market in the 1990s were on average technically more reliable than those in the 1980s. Also technical development in the form of borehole heat exchangers extended the application possibilities of GSHPs.

(2) Energy prices: The fierce competition between power and oil companies evened out in the 1990s, and energy prices started to rise again (Fig. 1.), thus improving the competitive position for the GSHP sector. Together with the technical development, this has become a key factor behind the growth of the GSHP trade. In Finland the development was initially cautious whereas in Sweden GSHP sales soared after 1995 (Fig. 2.).

(3) Developing distribution channels and familiarity of the technology: At first the specialised retailer networks gave credibility and reliability for the relatively unfamiliar heat pump technology since the 1990s. Later on heating and plumbing contractors have come along and increased the installation capacity as sales volumes have gone up. Meanwhile the expertise and credibility of the industry were improved by the training and certification scheme created by the Finnish Heat Pump Association at the beginning of the 2000s, and later on the EUCert program.

(4) In the 2000s environmental policy and legislation have had a double role in shaping the GSHP industry in Finland: On the one hand they have contributed to the deployment of GSHPs through subsidies. On the other hand, regulations have been introduced to control the expanding industry.

The 72 % increase in GSHP sales from 2010 to 2011 is an example of how legislation can affect the industry. The increase was generated by three legislative factors, which encouraged customers to act sooner rather than later: it had been announced that 2011 would be the last year of government subsidies for GSHP installations; the planning permission procedure for ground loop heat exchangers came into effect; and a decrease in the tax deduction for household and renovation work was due after 2011.

In addition to the above mentioned factors, the general economic trend in Finland has strongly influenced the GSHP industry in recent years. The economy has been in recession for several years, and the building trade has been slow. Although sales in absolute numbers have decreased, GSHPs have become relatively more popular so that more than 50% of new single-family homes in Finland had a GSHP installed in 2013-2015 (Motiva 2016:11).

4.2. Policies and legislation: Practitioners' views and international comparisons

The value of trained and qualified GSHP installers and drillers, as well as designers and architects has been highlighted in international reports (Ground-Reach 2008, REGEOCITIES 2013) and EU legislation (the RES Directive 2009/28/EC, Article 14). The importance of training for securing quality emerged also in many questionnaire responses, but the current qualification requirements received some criticism. The lack of law enforcement has prevented the environmental benefits from being fully realised. It has also increased inequality between contractors: While some contractors have had their personnel trained with high costs, other contractors have neglected this without sanctions, thus saving a considerable amount of time and money. Nyborg & Røpke (2015) have identified similar issues regarding heat pump training in Denmark, namely costs, and the training not being obligatory.

The planning permission scheme for ground loop heat exchangers (GLHEs) has entailed several benefits: adjoining properties and their heating needs are considered in positioning GLHEs; building of GLHEs can be regulated by writing building specifications into the permissions when necessary; construction may be forbidden on vulnerable groundwater areas and close to groundwater pumping stations; and the locations of GLHEs can be recorded in a database.

The permission procedure also caused some criticism, apparently not so much due to the extra work load but more due to the slow and increased bureaucracy and confusion related to the implemented permission process. These issues have been considered in a recent evaluation report (Tarasti et al. 2015) that suggests improvements to make the procedure clearly defined, standardized and expedited in line with the EU legislation (RES Directive 2009/28/EC, Article 13). Building standards for borehole heat exchangers should be incorporated into the system as has been done in many municipalities in Sweden (Jardeby et al. 2013; SGU 2008). Building standards were also supported by most questionnaire respondents, which suggests that practitioners have commonly perceived the deficiencies in quality and the lack of consistency in building practices as a problem.

From the users' point of view, mandatory standards for borehole heat exchangers, as well as developing the qualification requirements, would promote quality assurance. These measures would simplify the shopping process, when the customer would not need to be concerned about the basic functionality of the system. The shopping process may also become easier if customers can have personal consultation with an impartial expert (Heiskanen and Lovio 2010; Heiskanen et al. 2014). For enterprises, counselling services by government or local authority energy consultants, or enterprise energy efficiency programs have been proposed (e.g. DeCanio 1993;

Thollander et al. 2007; Meath et al. 2016). In Finland there are ten regional energy information agencies (www.eneuvonta.fi/etsi-lahin-neuvoja). Information or guidance programs for citizens are also required in the RES Directive (2009/28/EC, Article 14). In Sweden all municipalities offer free energy advice services (Nair et al. 2010). Mahapatra et al. (2011a, 2011b) conducted questionnaire studies among Swedish energy advisers and Swedish homeowners. In the light of their findings, an important issue in developing energy advice services is e.g. providing sufficient training for the advisers as they need to have broad expertise on different energy forms.

Public subsidies for heat pump installations were available on a larger scale in Finland from 2008 to 2011. This study has found both positive and negative aspects related to subsidies. On the one hand they conveyed governmental approval and a financial incentive for house owners. On the other hand the subsidies distorted competition, and attracted large numbers of new, often inexperienced contractors to the trade. An essential deficiency in the subsidy program in Finland was that no quality requirements were incorporated, unlike in e.g. Norway and Denmark (Bjørnstad 2012; Nyborg & Røpke 2015). In order to receive the subsidy for a GSHP project in Finland, no requirements were imposed on the construction of the system, quality of the components, or qualification of the installers. This lack of quality incentives, together with the overcapacity, seems to have contributed to the unfolding of the unhealthy price competition at the expense of quality. In this respect the subsidy failed as a policy measure, since the original aim of the Finnish policy makers was not a decline in quality. By now the heat pump sector in Finland has reached such a volume that public subsidies no longer appear an efficient policy measure to promote the industry (cf. Lund 2007b).

Sweden has offered public subsidies for GSHP installations intermittently since the 1970s until 2010. The subsidies caused problems there as well. Åstrand et al. (2005) pointed out that the 1984 subsidy scheme in Sweden was deficiently planned and actually compounded the problems that the industry later faced: first the scheme over-heated the market, and then its abrupt termination shocked the already staggering industry. As a reason for this Åstrand et al. identified the lack of stakeholder participation in policy drafting. Also in the 2000s the uncertainty about the duration and magnitude of the subsidies proved problematic in Sweden when the manufacturers hesitated over making investments in technology development (Kiss et al. 2012). Meanwhile Switzerland subsidized retrofit heat pumps only in 1993–1995. The subsidy was discontinued after a survey revealed that 85 % of the recipients would have purchased the system also without the subsidy. After this subsidy experiment the funding was redirected into further improvements on training, quality and informing the public (Rognon 2008).

Lund (2007b) compared the effectiveness of subsidy-based and catalytic policy measures in creating energy impacts. He found that commercialization and cost effectiveness are better realized with catalytic measures such as controlled experimentation of options, different procurement forms, and information dissemination. Lund thus recommends that catalytic measures should be given more consideration. The Swiss definition of policy has been in line with Lund's recommendations. The Finnish heat pump policy, on the other hand, has been mainly subsidy-oriented, and Sweden has applied both catalytic and subsidy-based policies.

5. Conclusions

The results of this study show that since the 1990s, the development of the GSHP industry in Finland has been influenced by developing technologies, energy prices, developing distribution channels and familiarity of the technology, and especially in later years by the national

environmental policy and legislation. The Finnish GSHP industry has increased its market share steadily since the late 1990s, and currently more than 50 % of new single-family homes have GSHPs installed.

This study indicates that quality assurance has so far not been among the central principles when planning Finnish GSHP policies. Although it is an essential factor for user satisfaction, environmental protection, and the success of the industry, quality requirements were omitted from the former public subsidy program for GSHPs. Also the current legislation could be developed to improve quality. For example the GSHP installers' refrigerant qualification could be replaced with more extensive qualification requirements to guarantee that the installers can deliver good quality for their customers. Also the planning permission for ground loop heat exchangers should be complemented with binding standards for ground loop heat exchangers.

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