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Accelerating the deployment of shallow geothermal heat and cold resources in Europe

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ABSTRACT

The principle objective of this paper is to promote the large scale deployment of shallow geothermal heat and cold in Europe. Based on Europe wide potential estimates and several shallow geothermal case studies in the building sector, it is shown that for a real large scale deployment the perception on and sustainable deployment of this resource have to change. Decision makers have to become aware of 1) its potential in terms of both supply and demand 2) the benefits for the end-user and society as a whole and 3) the possibilities for innovative financing schemes.

This paper shows that the shallow geothermal potential in Europe is by far sufficient to supply heat and cold to all European citizens. In addition, it shows that there is a large market for geothermal heat and cold in Europe. An important breakthrough can be established by making decision makers aware of their national and regional potential and by communicating that it is energetically much more efficient to use geothermal heat and cold directly, instead of burning limited -and increasingly more expensive- fossil fuels.

The Kyoto protocol and the recently set target for a 20% share of renewables in 2020 are expected to create extra momentum in the process of accelerating its deployment, but more importantly, a win-win situation for governments, companies and end-users of geothermal heating and cooling is to be marketed and recognized. This means that apart from the political facilities and incentives that governments should provide to attract companies to invest in geothermal resources; political willingness is enhanced when governments also benefit from its deployment, e.g. by a reduction of environmental problems in cities or through a financial benefit in geothermal heat and cold projects. Several innovative financing schemes are proposed to overcome the initial financial barrier.

In conclusion, shallow geothermal energy resources are in fact a gold mine for Europe. Lets now act jointly in Europe to profit from it.

1. INTRODUCTION

A transition from a world depending on fossil fuels to a world running on renewable energy sources is inevitable, simply because mankind cannot indefinitely continue to base its activities on the consumption of finite resources. In addition, there is a growing awareness of the detrimental effects of burning fossil fuels and the importance of an increased use of clean and renewable energy sources. Geothermal energy is a renewable energy source, which has been utilized for over a century, either to generate electricity or to use directly. Only a small fraction of the huge potential of this widely available renewable energy source[1] is used today. In the 25-member European Union the installed electrical capacity was 843 MWe, producing nearly 5.2 TWh (mainly in Italy) at the end of 2005. The thermal installed capacity in these countries was roughly 7.5 GWth at the end of 2005. The last figure includes 5.4 GWth of heat pumps (Geothermal barometer, 2006)[2]. Moreover, shallow geothermal energy has many advantages in terms of continuous availability, low operating costs and as an environmentally benign energy source. Remarkably though, geothermal energy generally has not received as much attention as would be expected. Besides its large potential, the European Commission target of a 20% share of renewables in 2020 should be able to accelerate the utilization of renewable energy sources, including geothermal resources in the EU. Nevertheless, several requirements have to be met to overcome the barriers that are currently present, before large scale deployment of shallow geothermal resources will be achieved in Europe. The principle objective of this paper is to propose some of the essential requirements, based on several large scale shallow geothermal case studies in the building sector. It focuses on shallow geothermal resources, which are situated at a depth of a few tens to about 300 meters. In brief, the paper discusses the aspects that need to be dealt with in order to change the perception on shallow geothermal energy and promote its deployment.

The paper starts with a discussion on the concept of shallow geothermal applications and their advantages for both end-users, developers and society as a whole. Then, an estimation of the European potential for shallow geothermal energy both in terms of resource potential as well as market potential is made. After these introductory sections, several Dutch case studies are introduced that serve to illustrate market opportunities. Three innovative financing schemes are presented in this section. It is discussed how end-users, developers and national governments can all benefit from the deployment of shallow geothermal resources. The paper is finalized with a discussion and summary of the aspects that are expected to bring about a change in perception and accelerating deployment of shallow geothermal energy.

2. CONCEPT AND ADVANTAGES

2.1 Concept

Shallow geothermal applications, i.e. Aquifer Energy Thermal Storage (ATES) and Borehole Heat Exchangers (BHE), use the heat and cold that is stored in the subsurface for the heating (in winter) and cooling (in summer) of buildings. The groundwater at a depth of about a few meters up to several hundreds of meters normally has a constant temperature that is roughly equal to the average yearly temperature at that location. Energy is used for the

[1] 5000 EJ/yr worldwide as stated in the World Energy Assessment, 2000

[2] These figures exclude countries such as Iceland, Switzerland, Russia and Turkey that also have a substantial capacity installed

extraction and circulation of the water and for reaching the required temperature in winter with a heat pump.

In figure 1 a schematic ATES system is shown. It can be seen that there are two wells, one for producing heat in winter and one for producing cold in summer. Between winter and summer the production well becomes an injection well and vice versa. After several years, the temperature around the well used for heating has slightly increased and the temperature around the cold producing well has slightly reduced. A situation can be achieved in which there is a balance between the heat extraction and heat return to the subsurface over a period of a year. This balance can be maintained for a very long time period.

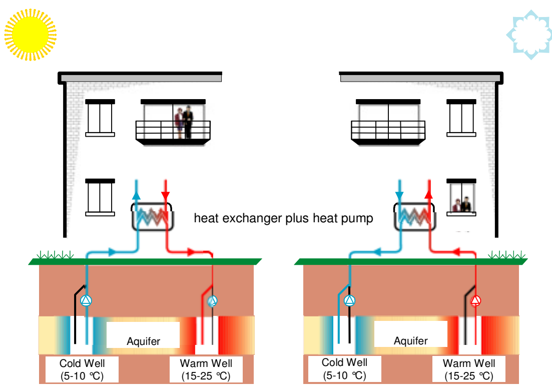

Figure 1: Schematic picture of an ATES system in summer (left) and winter (right)

2.1 Advantages

Shallow geothermal energy uses rather simple concepts and mature techniques for both Aquifer Thermal Energy Storage (ATES) systems and Borehole Heat Exchangers (BHE). Its production is independent on weather and requires only a small land area. Geothermal energy resources are continuously available, 24 hours a day and year round, and they have a potentially high capacity factor. Shallow geothermal resources can be used for both heating and cooling. Furthermore, geothermal resources have an inherent storage capability and can be used in combination with various other renewable energy sources, like solar heaters or surface water.

The fact that shallow geothermal energy also provides the comfort of cooling, increases the competitive edged and hence reduces the payback period of such applications. By using low temperature heating systems, residents generally experience a very comfortable way of heating and cooling compared to high-temperature central heating systems with fossil fuels or cooling by circulating air from air conditioning systems. This can be explained by the fact that the heat and cold is distributed equally through the living space, thereby reducing air movement. On top of that, no radiators are needed anymore, thus creating extra living space.

Developers and suppliers can benefit from an accelerated use of ATES and BHE systems through the turnover of their energy services, installations and products. Systems can be applied in both existing as well as new buildings. As will be presented later in this paper, this means that there is already a potentially large market for shallow geothermal applications present today.

2.2 Efficiency

A gas heater has a very high efficiency of over 100%. However, it is energetically more favorable to use a low temperature heat source for heating buildings instead of burning primary fuels. By using the thermal energy from the subsurface with a heat pump, an efficiency[3] of up to 200% can be achieved, based on primary energy input. The efficiency of a heat and cold storage system is higher than the alternative natural gas system, because a lot of the produced energy is already provided by the subsurface, which can be subtracted with relatively little extra energy. The concept is illustrated in the in figure 2, which shows the temperature at the Kelvin scale, the temperature at the side of the aquifer that is used for cooling (5°C) and for heating (25°C). It shows that there is relatively little extra heat needed to reach the required temperature for a low temperature heating system (40°C) and for a high temperature heating system (60°C).

Cooling is done by letting the water circulate through the heat exchanger in the building, without using a heat pump. For cooling the reference coefficient of performance (COP) for a compression air cooling system is 2 to 3, whereas the COP of a heat and cold storage system is more than 20. An efficiency of roughly 40% for electricity production also has to be taken into account for both cooling applications. This implies that a large reduction of 50-80% in greenhouse gas emissions is possible; hence, the use of shallow geothermal fits very well in the long term targets of the European Commission.

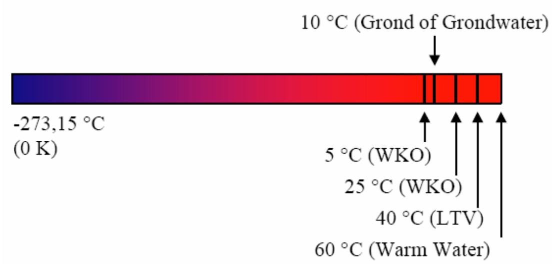

Figure 2: Kelvin temperature scale showing the temperatures of a heat and cold producing aquifer and the little extra energy needed for heating houses at 40°C or 60°C (TNO, 2004).

3. POTENTIAL

3.1 Current energy supply and demand

Currently the greater part of the energy demand in Europe, including heating and cooling, is still supplied by fossil fuels. The EU is even thought unlikely to reach a contribution from renewable energy sources over 10% by 2010 (Renewable Energy Road Map, 2006). In the EU about one third of the final energy demand is used for heating and cooling[4] (Eurostat and *PRIMES* model, 2000). Currently, the energy demand for heating and cooling is about 16-17 EJ per year (Eurostat, 2006). This means that there is a large market potential for renewable heating and cooling.

[3] The efficiency is defined as the ratio between energy wanted (heat) divided by the primary energy input. Energy needed for extracting fossil fuel (coal or gas) for electricity production is not taken into account.

[4] Based on primary energy 23% is for heating and cooling

3.2 Potential of shallow geothermal

The potential for shallow geothermal energy (ATES and BHE systems) is enormous in Europe. A simple estimate has been made, based on the total surface area of Europe (10,200,000 km^2) and an area needed of 17 m^2 per GJ for ATES systems and 34 m^2 per GJ for BHE systems[5]. As BHE systems can be used practically anywhere (100%) and ATES systems at roughly 50% of the land surface, the average maximum amount of recoverable energy from shallow geothermal resources in Europe is over 600 EJ per year. If only 10% of this amount would be economically exploitable, still 60 EJ can be exploited every year. For the European Union the exploitable shallow geothermal energy resources contain roughly 27 EJ/yr. Hence, this remaining potential is enormous and sufficient to supply all EU citizens with heating and cooling throughout the year, also when an increase in demand is taken into account.

As an example, the Netherlands has an enormous potential due to its location in a delta formation with sedimentary deposits from rivers such as the Rhine and Maas. These water bearing sedimentary beds are the reason why the greater part of the Netherlands is suitable for ATES systems (roughly 90%). In the less suitable areas, heat can be mined from the subsurface through BHE systems. Estimates have been made of the freshwater capacity being roughly 800 10^9 m^3 (TNO, 2003). On top of that, the brackish water comprises an additional capacity of several multiples of the fresh water capacity. This means that theoretically the full heating and cooling demand of all buildings in the Netherlands can be supplied by shallow geothermal resources. Based on the surface of the Netherlands the total potential is roughly 2.2 EJ/yr for ATES systems and 1.2 EJ/yr for BHE systems. The potential for ATES systems relative to the potential for BHE systems is large compared to the European ratio of ATES and BHE systems. This can be explained by the fact that the Dutch subsurface is very suitable for the ATES system, which is the preferred system due to its more efficient use of the subsurface.

3.3 Reserve value

As mentioned earlier, at the end of 2005, only about 7.5 GWth of direct applications with shallow geothermal energy were installed in the EU. This means that there is an enormous potential still unexploited. The full estimated potential of the exploitable European shallow geothermal resources as calculated above, are worth approximately 1,800 billion € per year (and 810 billion € for the EU-27)[6]. In the following picture the reserve values per year for ATES and BHE systems in Europe are shown.

Per inhabitant the reserve value for both ATES and BHE systems is 1,600 euro/yr to over 2,500 euro/yr for the EU and Europe respectively. Moreover, it is important to realize that this value is applicable for an unlimited time period as the system can be kept in balance forever. Clearly, there is an unexploited goldmine in the European subsurface.

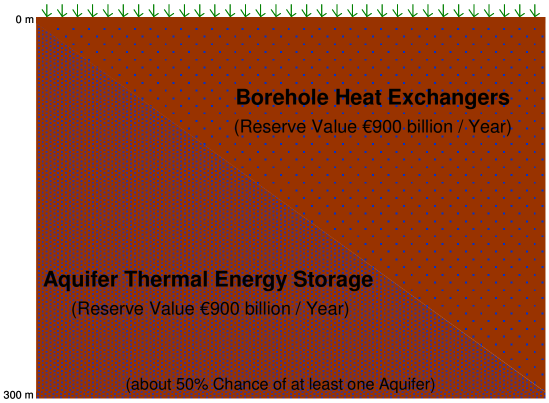

Figure 3: Estimates of the reserve value for Borehole Heat Exchangers and Aquifer Thermal Energy Storage in billion euros per year

4. ECONOMICS AND MARKET OPPORTUNITIES

4.1 General economics

A characteristic of geothermal heat and cold storage systems is that they are associated with high initial investments[7] and low operating costs, as opposed to conventional fossil systems that have relatively low initial investments and high operational costs due to fuel use. The investment cost per effective produced kW for ATES systems is about € 300/kW (IF Technology report). Operating costs are mainly made up of maintenance and electricity consumption by the heat pump. Depending on the heat and cold demand and the scale of the application, a project has a payback period of about 3-10 years[8].

The determining factor for the large scale breakthrough of shallow geothermal resources for a sustainable heat and cold supply is the financial approach of primarily its initial investment costs, but also operation costs during its lifetime and the share of the benefits on both the short and long term. Only when consumers, developers and the government can all benefit from the exploitation of shallow geothermal resources can shallow geothermal energy become the standard in Europe.

4.2 Case studies

Various innovative financing mechanisms will be introduced and illustrated with three case studies in the building sector. These financing mechanisms overcome the barrier of the higher than usual initial investments and the required long term commitment of the various actors involved.

The following case studies will be presented:

1. Project Helianthus in the province of Friesland (the Netherlands) showing the added value of an energy mortgage;
2. Project Ouverture in the city of Goes (the Netherlands) showing the added value of the Energy Service Company approach;
3. Larenstein, de Bilt (the Netherlands), showing the long term commitment of the local government in a renewable heating and cooling project.

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[5] Assuming an energetic balance in the subsurface of 60 m^2 per MWh and 120 m^2 per MWh for heat and cold storage and borehole heat exchangers respectively (Novem, 2003)

[6] Assuming a price of 15 €/GJ for both heating and cooling

[7] Approximately €10.000-15.000 for individual dwellings and €5.000-10.000 per dwelling for joint projects (own figures)

[8] This estimate is based on own experience in various national and international projects

4.3 Financial mechanisms

4.3.1 Energy mortgage

For individual systems, an energy mortgage with a low interest rate can be the solution for the high initial costs. A financial organisation (a bank) takes the financial risks, with the shallow geothermal system plus heat pump and possibly other renewable energy systems as the pledge (security). The low interest rate can be accomplished when the government wishes to support renewable energy systems. The monthly costs can then easily be paid, because the operational costs are much lower than in the case of natural gas fired systems. Presently both the Rabobank and the Triodos bank offers in the Netherlands the energy mortgage solutions.

An example of this approach is the Helianthus project in Zwaagwesteinde, the Netherlands. In the project Helianthus, project developer Seinen has built 24 houses for first time buyers. The houses use only 25% of the normal energy usage of equivalent new houses, by incorporating borehole heat exchangers, a heat pump, low temperature heating and cooling plus 3 kW peak photovoltaic solar panels. By putting the initial investments for the renewable energy systems in a energy mortgage, the owners have monthly costs of only € 450 for both the mortgage and the energy bill. This enables people to enjoy a high quality and quality house under the local price level for rental houses.

4.3.2 Energy Service Company (ESCO)

When house owners are not capable or do not want an extra mortgage but prefer an Energy Service Company to take over the investment plus exploitation, the financial model is the so-called ESCO-model (Energy Service Company). In general, a collective system is then realized with one or more doublets (a pair of wells), water supply and return distribution system and collective or individual heat pumps. The house owners then have a collective contract with the ESCO which details the entrance fee (initial onetime payment), the yearly standing charge (for maintenance costs) and the price per GJ heat and GJ cold. These price components can be linked to the reference costs for heating and cooling (as was done in the case of Goes, the Netherlands), the actual costs of the renewable energy system plus a reasonable margin for the service company or a combination of both.

Figure 4: Picture of the Ouverture area in Goes (the Netherlands), one of the first areas in which heat pumps were applied on a large scale (about 340 houses).

Since the fossil fuel prices in Europe are increasing year after year with more than 10%, consumers would also like alternatives to the price link with reference fossil based heating systems. An alternative approach is to agree on a fixed increase percentage (in the order of 4-5% per year) for heat and cold over the whole contract period (30 years). This approach gives maximum security against the expected world wide price increases of heating oil and gas but also minimizes financial risks for the energy service company. Lower risks for the ESCO also results in lower yearly costs for the households.

4.3.3 Government role

The government benefits from the deployment of shallow geothermal applications through the cost-effective way in which the greenhouse gas emissions and the environmental problems in cities due to fine dust particles are reduced. Since ATES and BHE systems pave the way for large-scale usage of geothermal heat and cold, the shallow subsurface (from 0 till about 300 m depth) represents an appreciable financial value (see paragraph 3.3). The first role that the government i.e. province or municipality can play is a coordination role in order to optimally make use of the subsurface and the various aquifers.

It is also thinkable that the government would like to stimulate the deployment of shallow geothermal resources by implementing policy measures in favour of renewable heating and cooling. So far the political focus has been on renewable electricity mainly. Renewable heating and cooling, including shallow geothermal options have not received adequate attention, which is surprising when the large demand for heating and cooling is considered (one third of the final energy consumption in the EU). Several initiatives, such as the Renewable Heating Action Plan for Europe by EREC (2007), are expected to increase the awareness among policy makers of the enormous potential for renewable heating and cooling.

Furthermore, it might be beneficial in some cases that the (local) government participates financially in energy service projects (heat and cold companies) on a sound return on investment basis. Normally, the market should take the initiative to realize a shallow geothermal project. However, a successful example of a Province which was willing to invest in renewable heat and cold is the collective heat and cold storage system for the project of a small business park Larenstein (about 40 companies) in De Bilt (the Netherlands). By proposing to invest a substantial part in the heat and cold system, the province gets its investment back in the second half of the 30-year contract period by adding a small percentage (say 0.25 to 1%) to the yearly fixed heat price increase (4 to 5%). By doing so, the government removes short term financial obstacles, demonstrates commitment to a transition to renewable energy but also respects sound business principles.

5. CONCLUDING REMARKS

It is clear from this paper that there are various reasons why the use of shallow geothermal resources is a realistic and advantageous option for a sustainable heating and cooling supply for all European citizens, especially when the innovative financing mechanisms as proposed in this paper are considered.

An important breakthrough in the deployment of shallow geothermal energy can be established by making decision makers aware of:

- their national and regional potential, also in terms of financial asset;
- the enormous heating and cooling demand in most EU and European countries;
- the large potential for greenhouse gas emission reductions;
- the simple techniques and available experience with ATES and BHE systems;
- the fact that it is energetically much more efficient to use (geothermal) heat and cold directly, instead of burning limited -and in time even more expensive- fossil fuels;
- the possibility of smart financial mechanisms such as the energy mortgage and the ESCO company

It is concluded that the shallow geothermal potential in Europe is by far sufficient to supply heat and cold to most, if not all EU and European citizens. In addition, it shows that there is a large market for geothermal heat and cold in Europe. The shallow geothermal resource base represents an enormous economic value of many hundred billions of euros every year for Europe as a whole that is available for an unlimited time period. Furthermore the advantages are apparent for both consumers (comfort and a continuous energy supply), developers (increasing turnover and a large market) and society (sustainable heating and cooling, with minimal greenhouse gas emissions) as a whole.

The financial mechanisms presented in this paper show that there are several possibilities to overcome the barrier of the initial investment and the possibility for a long term commitment and sharing of financial benefits by various actors involved. It is indeed possible to all profit from this renewable energy source. It can be concluded that shallow geothermal resources are in fact a gold mine for Europe, but only if it were perceived and dealt with in that way.

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