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Important criteria for ATES legislation

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Abstract

In their paper on the International legal status of the use of shallow geothermal energy, Haehnlein et al. (2010), showed that in many countries there is hardly no or very limited regulation regarding open well and closed loop geothermal systems. The lack of any regulation seems to be attractive to apply the technology, but the European RegeoCities research program found out that a lack of regulations will become a threat for a proper introduction of the technology. Setting up a proper legal framework is not so easy, due to the many interests, especially in the protection of the groundwater. In this contribution, we explain how this was done in the Netherlands. Topics addressed are the historical developments, ownership of the stored thermal energy, recent policy changes based on the results of several large-scale research projects, subsurface spatial planning and ATES in contaminated areas.

Keywords:

ATES, Aquifer Thermal Energy Storage, criteria, legislation, legal framework

1. Introduction

Over the last century, land subsidence has been a problem in many industrial cities. This land subsidence was related to excessive groundwater extraction and the associated decline in groundwater levels (e.g. Kaneko and Toyota, 2011). To solve the subsidence problems, an experiment was begun in 1958 in Shanghai, to recharge aquifers through injection wells. By 1965 it was realized that injection was beneficial, not only for controlling land subsidence and raising the groundwater level, but also for improving the groundwater temperature and quality for later use (Yan and Woo, 1981). The observation that the injected and "stored" water maintained its cool temperature for months demonstrated the feasibility of thermal energy storage (Morofsky, 2007).

In the 1980’s, several provinces in the Netherlands restricted groundwater mining for industrial cooling, but left an exemption if reinjection using ATES for cooling were implemented. This stimulated interest in ATES led to many implemented projects (Morofsky, 2007). The success of the first projects in the second half of 1980’s and the good economy and the environmental advantages of ATES, resulted in an exponential growth in the following years. Here, the government had a stimulating role both by providing subsidies for sustainable techniques and by gradually increasing the energy efficiency requirements for new buildings. A recent inventory shows that the number of permits for open-loop shallow geothermal energy systems in the Netherlands was about 2,200 at the end of 2016. The vast majority of these permits (on estimate > 90%) is for ATES systems. It has to be noted, that the actual number of systems is expected to be much higher, because a permit is not always required for small systems.

In their paper on the International legal status of the use of shallow geothermal energy, Haehnlein et al. (2010) showed that in many countries there is hardly no or very limited regulation regarding open-loop and closed-loop geothermal systems. The lack of regulations/legislation seems to be attractive to apply the technology, but the European RegeoCities research program has shown that a lack of regulations is a potential threat for a proper introduction of the technology. Setting up a proper legal framework is not so easy, due to the many interests, especially in the protection of the groundwater. In this contribution we will explain how this was done in the Netherlands.

2. Ownership of stored heat and cold

When ATES is introduced in a country, one of the legal aspects that will have to be solved is the ownership of the thermal energy that is stored in the subsurface. According to the Dutch Law, the ownership of the ground consists of the ground surface and the earth layers below. Also the groundwater that has come to the surface by a pump or well and water on the surface that is not connected to water on another's property are own property. The groundwater itself isn't. Therefore, the ownership of thermal energy is not easy to answer. The heat and cold is not only stored in the groundwater (not anyone's property), but also in the ground itself (solid part: grains, rock, owned by the concerning land owners). The thermal energy is "added" to groundwater that has been pumped to the surface (and is thus owned by the land owner) and is subsequently pumped back into the subsurface making it groundwater again. Although there is no clear answer (no jurisprudence available), the impression is that the stored heat and cold should be treated as 'groundwater' and is therefore not anyone's property (Putter and Aerts, 2006). This makes it possible to store heat and cold below someone else's property, but also introduces a problem: if the stored heat and cold is not anyone's property, it can also be recovered by someone else.

3. ATES initial framework

When the first projects were designed, specific legislation for ATES systems was not in place. The most relevant legislation was the Groundwater Act (later this became the Water Act). The Water Act makes it possible to apply for a permit to extract (and re-inject) groundwater. By applying for a Groundwater Permit for an ATES system, the system owner acquires the right to extract and inject groundwater for thermal energy storage.

To apply for a permit an environmental impact assessment has to be performed. During the permit procedure, the authorities (the concerning Province) judge if the environmental impact of the system is deemed acceptable. In general, it is not allowed to (significantly) adversely affect the environment and/or other stakeholders. This means that an existing ATES system is protected against adverse effects of new ATES systems or other groundwater extractions. In that way the stored heat and cold is also protected.

Another important group of stakeholders are the drinking water companies. Public water supply well fields typically have a legally enforced groundwater protection zone. In a groundwater protection zone, which is usually the area through which the travel time of groundwater to the well is less than 25 years, ATES systems are not allowed. Furthermore, a number of provinces have reserved certain aquifers/depth ranges for drinking water production. One of these provinces recently adjusted their policy by differentiating between urban areas (ATES possible in the aquifer that was previously reserved for drinking water production) and other areas (aquifer reservation maintained).

3.1 Developments in permit conditions

The Groundwater Act was designed as a legal framework for groundwater extraction (and injection). Changing the temperature of the groundwater was not anticipated in the Groundwater Act. One of the main concerns was therefore the possible effect on the (bio)chemical groundwater composition. Because of the uncertainties concerning the environmental impact of an ATES system, especially the impact of temperature changes on the (bio)chemical groundwater composition, the first projects were permitted as pilot projects. The permit was valid for a limited period (usually 4 years), after which the permissibility had to be re-evaluated. In the first permits a significant monitoring effort was prescribed. The monitoring results had to be reported and evaluated to assess the environmental impact.

Because of the relatively high risk (technical problems related to a new technology, uncertainty about getting a final permit) and costs associated with the prescribed monitoring (e.g. drilling of monitoring wells, groundwater sampling, analysis of groundwater samples, evaluation of monitoring data) the first projects were partly funded/subsidized by the government. At the same time, the government was the institution to judge the permit application and the environmental impact, which required careful tuning between different ministries and the national and provincial authorities (Snijders, 2000). Research to solve technical problems and answer questions on environmental impact was partially undertaken within national research programs and partly within the framework of the lEA Storage Programme (IEA-ECES).

Because evaluation of the monitoring results showed that the environmental impact of most ATES-systems (storing low temperature heat and cold) was limited (e.g. Winters, 1992; Snijders, 1994; Drijver and Willemsen, 2004), the temporary permit was usually extended or converted to a final permit. Furthermore, the monitoring requirements in new permits became less extensive and temporary permits became more and more sparse. At the beginning of 2000, over 100 projects applying cold storage, or a combination of cold storage and low temperature heat storage, were operational in the Netherlands. A summary of the lessons learned in the 1980’s and 1990’s, including the role of the government, is given by Snijders (2000).

In 2013 new policy became effective, that was specifically meant to regulate UTES (Underground Thermal Energy Storage, including closed loop systems (BTES) and open well systems (ATES)). In these new regulations, a standardized set of monitoring requirements is proposed, that is used by most of the provinces. Reference data that have to be provided are the borehole descriptions (including well screen depths and backfilling scheme), pumping test data, well locations and analysis of initial groundwater composition. During the operational phase it concerns the pumped volumes, extraction and injection temperatures, energy performance and the analysis results of groundwater samples (yearly reporting).

3.2 Development of new policy

After 2000, ATES became more and more a standard technique. In 2008, the ministry of housing, spatial planning and the environment (VROM) initiated a Taskforce to further stimulate UTES to help realizing the national targets to reduce energy use and greenhouse gas emissions (VROM Ministry, 2009). One of the recommendations of the Taskforce was to adjust legislation to better suit the application of UTES. At the same time the exponential growth of the number of ATES systems led to increasing concerns on their impact, especially from drinking water companies (e.g. Bonte et al., 2011). As follow up, several research projects were started to further investigate environmental impact/concerns. The most important projects were:

- Meer Met Bodemenergie (More with soil energy): a program supported by 35 main actors in the field of sustainable energy, groundwater protection, and spatial planning in the Netherlands (Drijver et al., 2010). The results have been reported in 11 reports (in Dutch), several conference papers (Hartog et al., 2013; Sommer et al., 2013) and two PhD Theses (Sommer, 2015; Ni, 2015).
- Effects of shallow geothermal energy, a PhD project supported by the joint research program of the Dutch Drinking Water sector (BTO). The results have been reported in a PhD Thesis by Bonte (2013).

In 2013 new legislation became effective that was specifically meant for UTES systems. The most important goals were to:

- Simplify the permit procedure for ATES systems;
- Regulate closed loop shallow geothermal systems (BTES);
- Prevent interference between different UTES systems;
- Introduction of a certification system for companies, to ensure the quality of the construction of UTES systems.

Some highlights on the results and the choices made in legislation:

- The effects of temperature on (bio)chemical groundwater composition are minimal for storage temperatures up to 25 °C when an energy balance is maintained: in that case the impact of mixing of groundwater from different depths is more pronounced. At higher temperatures, the impact of temperature becomes more pronounced (Hartog et al., 2013; Bonte, 2013). These results are similar to results from Germany (Griebler et al., 2016; Jesußek et al., 2013; Brielmann et al., 2009) and Belgium (Possemiers et al., 2014). The temperature limit for ATES systems remains 25 °C or has been reduced by some provinces from 30 to 25 °C. Higher temperatures are only possible, when an exception is made (site specific consideration required).
- For systems with an energy balance that store low temperature heat and cold, no significant effects are expected, which is based on literature, theory and monitoring data (Hartog et al., 2013). Systems that effectively heat up the subsurface over the years may have (somewhat) more pronounced effects. Independently, the shallow subsurface in urban area's is gradually heating up, both because of climate change and because of the urban heat island effect (e.g. Zhu et al., 2010). Systems that effectively

cool the subsurface (net heat extraction over the years) could partly compensate this heating. Therefore, the new legislation allows ATES systems with an energy balance and systems that may cool the subsurface by injecting a surplus of cold.

- Since the environmental impact is usually limited, the standard permit procedure has been simplified. The standard duration of the permit procedure has been changed to 8 weeks, instead of the 6 months in the past (in specific cases the authorities can decide that a longer period is required). Furthermore, the environmental impact assessment report has been standardized and simplified for small scale ATES systems (< 50 m^3/h) since their environmental impact is usually limited.

4. Subsurface spatial planning

The principle in the Groundwater Act is that the first who gets a permit, claims the rights for abstraction and injection of heat and cold and will be protected against adverse effects from other future groundwater users. The next applicant has to take into account the presence of the existing system: a new permit is only provided, when the impact on permitted ATES system(s) is acceptable. Otherwise the Groundwater permit for the new ATES system will be denied. In the startup phase, the number of projects was limited and therefore, this was not an issue. Due to the increasing number of systems, new ATES initiatives were confronted with the presence of existing ATES systems more and more often.

When no adverse effects are allowed, the grow of systems is resulting in limitations for future ATES initiatives. The authorities have recognized this issue. Now, they have introduced the possibility to regulate subsurface spatial planning of UTES systems through a “masterplan”. The goal of such a “masterplan” is a fair distribution and optimum use of subsurface. It regulates which types of UTES systems are allowed and where they can be placed. This is especially important in case the thermal energy demand is higher than can be provided from the subsurface. For ATES this can be the case in areas with a limited cumulative thickness of suitable aquifers (at feasible depths) (e.g. Herbert et al., 2012) and/or in areas with a high energy demand per km^2 (e.g. Bakr et al., 2013; Caljé, 2010). In critical areas it can be considered to allow more interference between different UTES systems, in order to increase total energy savings (Sommer et al., 2015).

5. ATES in contaminated areas

Both ATES systems and groundwater contaminants typically occur in urban areas. In a strict interpretation, the Dutch Soil Protection Law prohibits the (additional) movement of contaminants. Since ATES systems often have large pumping capacities and displace relatively large volumes of groundwater, many ATES projects were not continued after the feasibility phase, because of the expected influence on groundwater contaminants (especially chlorinated hydrocarbons). The presence of contaminants and the Dutch Soil Protection Law, also seriously complicated the (re)development of urban areas (e.g. groundwater extraction for construction activities).

To solve these issues, an area-oriented approach was developed. Here, the municipality legally enforces a groundwater management area that contains a relatively high density of contaminants. Within a groundwater management area, it is allowed to move contaminants, provided that public health is not at risk. Causing spreading of the contaminants over the boundaries of the groundwater management area is prohibited. In this way, ATES was made possible in shallow aquifers in the contaminated zones of cities.

The development of the area-oriented approach also created opportunities for combining ATES and remediation (Slenders et al., 2010). On one hand ATES can be seen as a threat since it can promote spreading of contaminants (Zuurbier et al., 2013). However, additional groundwater movement can accelerate the dissolution of pure contaminant (especially chlorinated hydrocarbons) and promote mixing of contaminated and relatively clean groundwater. On the other hand, ATES is expected to promote biodegradation of contaminants: the increased volume of contaminated groundwater effectively increases the size of the "in-situ bioreactor", the additional groundwater movement improves the availability of the contaminants for the bacteria that perform biodegradation and the temperature changes (especially higher temperatures) are expected to accelerate biodegradation (Ni, 2015).

References

Bakr, M., van Oostrom, N., and Sommer, W.T. (2013). Efficiency of and interference among multiple Aquifer Thermal Energy Storage systems; A Dutch case study. *Renewable Energy* 60, 53-62.

Bonte, M., Stuyfzand. P.J., Hulsmann, A. and Van Beelen, P. (2011). Underground Thermal Energy Storage: Environmental Risks and Policy Developments in the Netherlands and European Union. *Ecology and Society* 16(1): 22.

Bonte, M. (2013). Impacts of shallow geothermal energy on groundwater quality - A hydrochemical and geomicrobial study of the effects of ground source heat pumps and aquifer thermal energy storage. PhD thesis, *VU University*, Amsterdam

Brielmann, H., Griebler, C., Schmidt, S.I., et al. (2009). Effects of thermal energy discharge on shallow groundwater ecosystems. *FEMS Microbiol Ecol* 68: 273–286.

Caljé, R.J. (2010). Future use of aquifer thermal energy storage below the historic centre of Amsterdam. Thesis, *Waternet Amsterdam/TU Delft*.

Drijver, B.C. and Willemsen, A. (2004). Temperature effects on groundwater composition – Summary of existing knowledge. *IF Technology*, report nr. 1/53232/GW.

Drijver, B.C., Henssen, M.J.C., Dinkla, I.J.T. H. et al. (2010). National research program on the effects of underground thermal energy storage (UTES) - Use of the subsoil in a sustainable way. Paper presented at *Consoil 2010* congres, Salzburg, Austria, september 2010.

Griebler, C., Brielmann, H., Haberer, C.M. et al. (2016). Potential impacts of geothermal energy use and storage of heat on groundwater quality, biodiversity, and ecosystem processes. *Environ Earth Sci* 75: 1391.

Hartog, N., Drijver, B., Dinkla, I. and Bonte, M. (2013). Field assessment of the impacts of Aquifer Thermal Energy Storage (ATES) systems on chemical and microbial groundwater composition. Paper presented at *European Geothermal Congress 2013*, Italy.

Haehnlein, S., Bayer, P. and Blum, P. (2010). International legal status of the use of shallow geothermal energy. *Renewable and Sustainable Energy Reviews*, 14(9), 2611-2625.

Herbert, A., Arthur, S. and Chillingworth, G. (2012). Large scale exploitation of Ground Source Energy for heating and cooling: resource constraints and management options in urban aquifers. Paper presented at *Innostock 2012* conference, Lleida, Spain.

Jesußek A, Grandel S, Dahmke A (2013a) Impacts of subsurface heat storage on aquifer hydrogeochemistry. *Environ Earth Sci* 69: 1999–2012.

Kaneko, S. and Toyota, T. (2011). Long-Term Urbanization and Land Subsidence in Asian Megacities: An Indicators System Approach. Chapter in: Taniguchi, M. (ed.), *Groundwater and Subsurface Environments: Human Impacts in Asian Coastal Cities*. Springer, 2011.

Morofsky, E. (2007). History of Thermal Energy Storage. In Paksoy H.O. (ed.), *Thermal Energy Storage for Sustainable Energy Consumption: Fundamentals, Case Studies and Design*. Nato Science Series II, 234, pp. 3-22.

Ni, Z. (2015). Bioremediation of Chlorinated Ethenes in Aquifer Thermal Energy Storage. PhD thesis, *Wageningen University*, Wageningen, NL, 216 pages.

Possemiers, M., Huysmans, M. and Batelaan, O. (2014) Influence of aquifer thermal energy storage on groundwater quality: a review illustrated by seven case studies from Belgium. *J Hydrol Reg Stud* 2:20–34.

Putter and Aerts (2006). Legal aspects of energy storage in the subsurface. *MILIEU & RECHT*, jaargang 33, nummer 7 (in Dutch).

Slenders, H.L.A., Dols, P., Verburg, R. and de Vries, A.J. (2010). Sustainable Remediation Panel: Sustainable Synergies for the Subsurface: Combining Groundwater Energy With Remediation. *Remediation Journal*, Vol. 20, Issue 2, p.143–153.

Snijders, A. (1994). ATES: water treatment and environmental impacts. *Proceedings Calorstock* '94. Espoo, Finland.

Snijders, A.L. (2000). Lessons from 100 ATES projects - The developments of aquifer storage in the Netherlands. *Proceedings TERRASTOCK 2000*, Stuttgart, Germany.

Sommer, W., Drijver, B., Verburg, R., et al. (2013). Combining shallow geothermal energy and groundwater remediation. *European Geothermal Congress 2013*, Italy.

Sommer, W.T. (2015). Modelling and monitoring of Aquifer Thermal Energy Storage Impacts of soil heterogeneity, thermal interference and bioremediation. PhD thesis, *Wageningen University*, Wageningen, NL, 204 pages.

Sommer, W.T., Valstar, J., Leusbrock, I., et al. (2015). Optimization and spatial pattern of large-scale aquifer thermal energy storage. *Applied Energy*, 137, 322-337.

VROM Ministry (2009). Green light for soil energy – recommendations Taskforce UTES (in Dutch).

Winters, A.L. (1992). Summary of research on microbiological processes. Annex VI, Subtask D., *University of Alabama*. Tuscaloosa. 37 pages.

Yan, Q.S. and Woo, T.F. (1981). The development and application of aquifer storage in China. *STES Newsletter*, III: 4-5.

Zhu, K., Blum, P., Ferguson, G., et al. (2010). The geothermal potential of urban heat islands. *Environ. Res. Lett.* 5.

Zuurbier, K.G., Hartog, N., Valstar, J., Post, V.E.A. and van Breukelen, B.M. (2013). The impact of low-temperature seasonal aquifer thermal energy storage (SATES) systems on chlorinated solvent contaminated groundwater: modeling of spreading and degradation. *J Contam Hydrol* 147: 1–13.